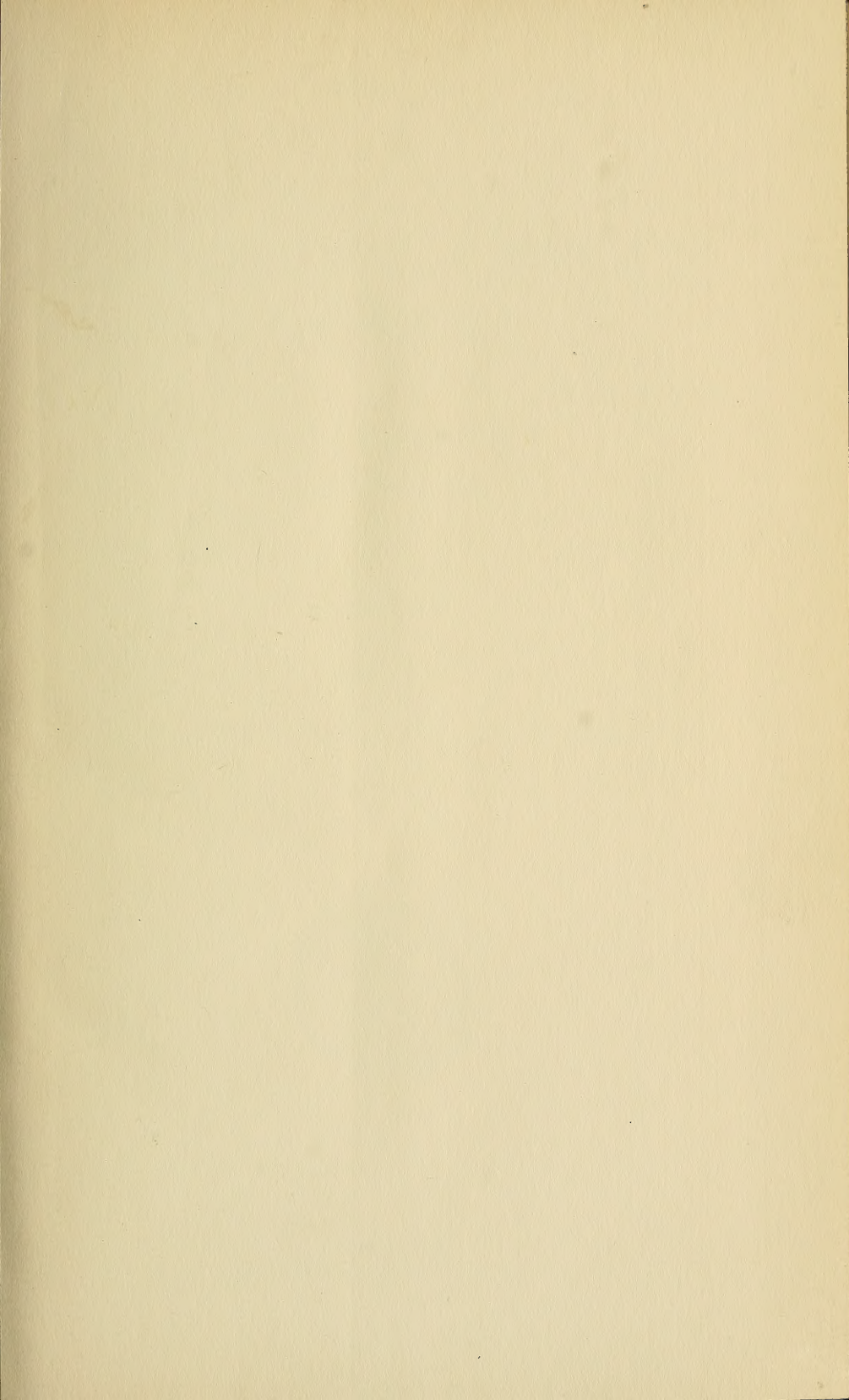


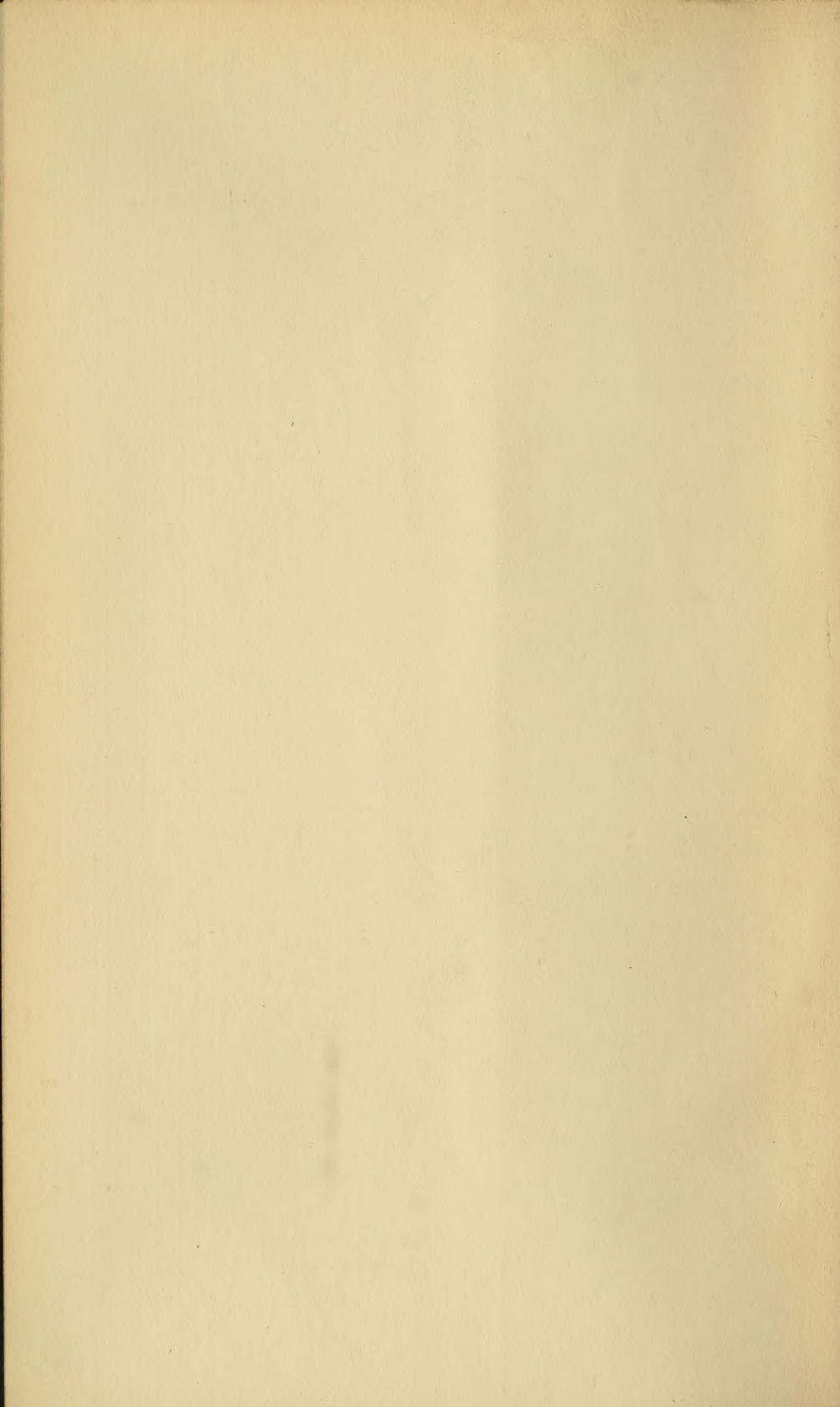
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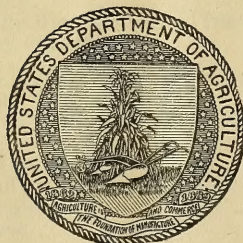
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THE CHEMICAL ANALYSIS OF WHEAT-FLOUR SUBSTITUTES AND OF THE BREADS MADE THEREFROM.

By J. A. LE CLERC, *Chemist in Charge*, and H. L. WESSLING, *Assistant Chemist*,
Plant Chemical Laboratory.

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OBJECT OF THE INVESTIGATION.

At present great interest is manifested in the subject of bread, as well as the various kinds of flour from which it can be made. Methods of making several varieties of bread, together with the place in the dietary occupied by bread, have been studied by the department and the results have been published.¹ This bulletin gives the results of the analyses of more than 30 part substitutes for wheat flour and the bread made from them. As very few authentic analyses of American bread materials and breads made with wheat-flour substitutes have been published, the results given here undoubtedly will be of value to millers, bakers, and housewives throughout the country.

ANALYTICAL WORK.

CHARACTER OF FLOURS AND BREADS ANALYZED.

Bread, as the unqualified term is understood generally in the United States, is the product made from wheat flour, salt, and water (with or without the addition of sugar, milk, etc.), leavened with yeast. The many other kinds of bread, such as rye bread, corn bread, salt-rising, and hot or baking-powder bread, usually are known by qualifying names to distinguish them from bread made entirely of wheat flour with yeast.

¹U. S. Dept. Agr. Farmers' Buls. 807 and 955.

Wheat flour always has been held in high favor as the principal ingredient of bread, because in the presence of water the protein of wheat yields a tenacious and elastic substance, called gluten, which has the property of expanding during fermentation, thus forming a network of cellular air spaces throughout the dough. During the baking process the gluten is so altered, or "set," that the cellular structure is retained, as a result of which there comes from the oven a light, porous loaf, unlike that produced from any other cereal flour.

FLOUR.

Standard flour.—As the experiments herein reported were carried on intermittently over a period of three years, it was impossible to obtain the same standard wheat flour for the entire series. Consequently the standard flour, which formed three-fourths of the flour content of the breads analyzed, varied in its composition. The flour used in making the loaf here designated as the standard contained 12.50 per cent protein ($N \times 6.25$), while the protein content of the bread of this standard loaf as analyzed was 8.74 per cent. Other wheat flours used in admixture with the substitutes considered in the course of this work varied in their protein content from 11.38 to 12.63 per cent, the breads naturally showing a corresponding variation in the protein content. This accounts for some apparent discrepancies in the protein content of the breads made with 3 parts of wheat flour to 1 part of substitute.

The substitutes used in these experiments may be classified as follows:

Group 1: Substitutes of low protein content or high carbohydrate content. They include the starches from different sources; fruits, such as the banana; roots, such as the cassava; tubers, such as the potato and the dasheen; and nuts rich in carbohydrates, such as the chestnut.

Group 2: Substitutes obtained from grains and cereals. Among these are the common cereals, as well as buckwheat, grain sorghums, and millet.

Group 3: Substitutes obtained from the legumes, including the peanut.

Group 4: Substitutes obtained from certain by-products, like bran, wheat germ, cotton seed, peanut oil cake, and soy-bean oil cake. Most of these flours or meals were obtained from the trade.

A few of the experimental flours were prepared in the Fruit and Vegetable Utilization Laboratory of the Bureau of Chemistry in this way: For Irish potato flour, the potatoes were pared, sliced, cooked in steam for about five minutes, then dried, and finely ground. The sweet potato flour was prepared by cutting the roots into long thin slices, spreading them on trays to dry in a current of warm air

until thoroughly dry and brittle, and then passing the dried product through a small hand-power mill. For the banana flour, large green fruit was used. It was peeled by hand, sliced, dried, and ground into a flour.

Of those prepared in the Plant Chemical Laboratory the chestnut, dasheen (peeled and unpeeled), rice (polished and brown), millet, bean, pea, chick-pea, and soy bean were first thoroughly cleansed and then ground in a hand mill, while rye, feterita, kafir, milo, and kaoliang were scoured and then ground in an experimental mill to give the desired flours. To obtain the peanut meal, roasted peanuts were crushed with a rolling pin.

The potato flakes employed in these experiments were obtained from Germany several years ago. The boiled potatoes were prepared in the laboratory by boiling potatoes in their skins, after which they were cooled, peeled, and mashed.

BREAD.

All the breads analyzed in this investigation were made from mixtures of flour, in the proportion of 25 per cent of substitute to 75 per cent of standard wheat flour.¹

METHODS OF ANALYSIS.

The methods for the analysis of cereal foods adopted by the Association of Official Agricultural Chemists² were used for all the determinations made, with the exception of the fat determination. As it is impossible to obtain accurate results for the estimation of fat in bread by the usual method of extraction, the Polenski method³ was employed for this determination. The carbohydrates were obtained by difference. The calories per pound were calculated by multiplying the sum of the carbohydrates and protein by 1,860, and the fat by 4,220, and then adding the two results thus obtained.⁴

RESULTS OF THE ANALYSIS.

Table 1 gives the composition of the standard flour and of the substitutes. The composition of the breads, as analyzed on the air-dry basis, is given in Table 2, and, as calculated on the basis of an assumed average moisture content of 35 per cent, in Table 3. In a general way, the data in these three tables have been arranged in the order of the protein content of the flour. Those showing a low protein content come first, being followed in turn by those prepared from grains and cereals, then by those made from legumes, and, finally, by those from certain by-products. Besides giving the composition of the various flours and breads studied, the tables

¹ The bread was made according to the directions given in U. S. Dept. Agr. Farmers' Bul. 955.

² Jour. A. O. A. C., Aug. 15, 1916, Vol. II, No. 2, part 2: 187.

³ Zt. Anal. Chem. 1911, 50: 655.

⁴ The calories were calculated by Rubner's factors.

show the nutritive value, in terms of calculated calories per pound, the color and texture of the loaf, and the amount of salt-free ash in the bread. Plates I to VII show very accurately the color and texture of the loaves of the different kinds of bread.

TABLE 1.—*Analysis of flour.*

Variety of flour.	P. C. No.	Water.	Ash.	Fat.	Fiber.	Protein (N×6.25).	Carbo- hy- drates.	Calories per pound.
Group 1 (low protein con- tent):		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	
Chestnut.....	13461	6.05	2.45	4.35	1.94	7.38	77.83	1,768
Cassava.....	10582	8.21	1.60	.29	2.01	1.44	86.45	1,628
Banana:								
Unripe.....	17259	7.85	2.65	.56	.87	4.04	84.03	1,661
Ripe.....	13174	2.35	2.96	1.03	.87	4.22	88.57	1,769
Dasheen:								
Unpeeled.....	13244	6.53	4.31	.60	2.33	8.25	77.98	1,629
Peeled.....	13245	7.48	4.12	.46	2.14	8.00	77.80	1,615
Potato:								
Dried.....	14659	6.82	4.01	.43	1.69	12.25	74.80	1,636
Flakes.....	14667	7.63	3.31	.29	1.75	5.70	81.32	1,630
Boiled.....	18086	80.72	.80	.05	.40	2.16	15.87	341
Starch.....	10608	13.69	.30	.12	.04	.35	82.83	1,552
Sweet potato.....	14671	5.98	3.42	.79	2.07	4.68	83.06	1,665
Group 2 (grains and cereals):								
Spring wheat.....	Standard.	12.00	.42	1.00	.25	12.50	73.83	1,647
Yellow corn:								
Raw.....	12883	6.96	.82	2.82	.69	7.88	80.83	1,768
Parched.....								
Steamed.....								
White corn:								
Raw.....	12884	7.21	.95	2.73	.79	8.25	80.07	1,758
Parched.....								
Steamed.....								
Rice:								
Polished.....	13485	9.65	.36	.24	.20	8.81	80.74	1,676
Brown.....	13603	10.20	1.07	1.47	.61	8.94	77.71	1,674
Buckwheat.....	13311	9.25	1.00	.92	.61	8.12	80.10	1,679
Rye (1.1 basis).....	13495	8.67	1.46	1.75	1.42	15.60	71.10	1,686
Oatmeal.....	(¹)	8.00	1.50	7.00	1.40	16.80	64.90	1,815
Feterita:								
Clear.....	14664	7.25	1.07	2.26	1.21	15.87	72.57	1,736
Patent.....	14663	8.02	1.04	1.87	.55	9.94	77.83	1,725
Millet.....	13625	11.19	.89	2.44	.51	14.94	72.03	1,683
Kafir.....	12291	11.38	1.43	2.59	1.00	14.12	69.48	1,664
Milo.....	12293	11.54	1.40	2.73	.91	13.37	70.05	1,667
Kaoliang.....	12292	11.41	1.57	3.04	1.03	13.31	69.64	1,671
Barley.....	17554	11.47	1.05	1.16	.45	8.69	77.18	1,636
Group 3 (legumes):								
Bean, white.....	13459	8.53	3.50	1.57	1.49	25.06	59.85	1,646
Pea, ordinary.....	13460	8.29	2.50	1.22	1.14	25.94	60.91	1,666
Chick-pea.....	14658	7.64	2.74	5.03	.99	20.44	63.16	1,767
Peanut.....	15325	2.82	2.18	49.40	1.54	29.31	14.75	2,905
Soy bean.....	13341	6.14	5.24	20.71	1.72	39.56	26.63	2,105
Group 4 (by-products):								
Bran.....	13306	7.86	5.26	2.90	6.22	18.00	59.76	1,550
Wheat germ.....	13755	6.92	5.42	10.64	2.17	32.63	42.22	1,859
Cotton seed, treated.....	12606	4.57	5.56	9.68	4.88	50.56	24.75	1,818
Peanut oil cake.....	18296	8.01	4.14	10.20	3.38	56.06	18.21	1,811
Soy-bean oil cake.....		6.25	5.97	5.93	4.37	45.45	32.03	1,691

¹ The average composition of oatmeal as given by König, et al.

TABLE 2.—*Analysis of bread, on the air-dry basis.*

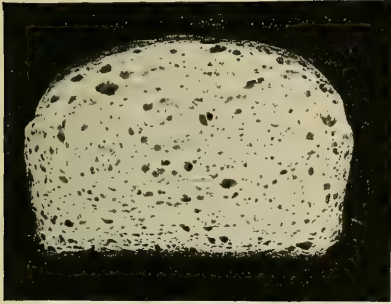
Variety of flour.	P. C. No.	Water.	Ash.	Fat.	Fiber.	Protein (N×6.25).	Carbo- hydrates.	Calories per pound.	Moisture in fresh bread.
Group 1 (low protein content):		<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>		<i>Per ct.</i>
Chestnut.....	13492	6.47	2.38	2.26	0.58	11.75	76.56	1,731	.....
Cassava.....	13352	6.72	2.23	2.28	.58	10.50	77.69	1,729	37.29
Banana:									
Unripe.....	13347	6.20	2.57	2.02	.41	10.56	78.24	1,740	38.22
Ripe.....	13348	7.81	2.34	1.71	.42	10.62	77.10	1,719	.....
Dasheen:									
Unpeeled.....	13343	7.37	2.83	1.60	.77	11.87	75.56	1,714	.....
Peeled.....	13344	7.38	2.85	1.72	.72	11.69	75.64	1,712	.....
Potato:									
Dried.....	14816	6.73	2.80	1.93	.57	13.19	74.78	1,724	36.08
Flakes.....	14819	3.27	2.42	2.34	.62	11.17	80.18	1,798	40.80
Boiled.....	14870	5.25	2.82	1.98	.50	12.40	77.15	1,749	42.01
Starch.....	13354	7.13	1.92	2.15	.20	9.81	78.79	1,700	34.60
Sweet potato.....	13355	5.12	2.61	2.17	.64	10.69	79.06	1,762	.....
Group 2 (grains and cereals):									
Spring wheat.....	13096	7.17	1.86	2.97	.19	12.63	75.18	1,759	38.29
Yellow corn:									
Raw.....	13100	6.96	2.01	2.90	.30	11.49	76.34	1,756	35.60
Parched.....	13098	6.74	1.94	2.88	.46	11.75	76.23	1,757	.....
Steamed.....	13102	6.06	1.94	3.59	.38	11.69	76.34	1,789	.....
White corn:									
Raw.....	13099	7.31	2.01	2.70	.32	11.75	75.91	1,744	36.10
Parched.....	13097	6.99	2.00	3.08	.44	11.69	75.80	1,758	.....
Steamed.....	13101	6.08	1.86	3.43	.35	11.87	76.41	1,786	.....
Rice:									
Polished.....	13487	7.47	1.86	1.84	.21	12.00	76.62	1,726	.....
Brown.....	13809	6.87	2.00	2.84	.25	12.00	74.66	1,758	.....
Buckwheat.....	13488	7.72	1.95	1.73	.27	11.75	76.58	1,713	.....
Rye (1.1 basis).....	13542	9.31	1.99	1.89	.44	13.25	73.12	1,764	.....
Oatmeal.....	13350	6.93	2.17	4.11	.43	14.00	73.31	1,797	35.29
Feterita:									
Clear.....	14823	6.35	1.96	2.00	.43	14.12	75.14	1,745	34.89
Patent.....	14822	7.11	1.93	1.98	.30	12.49	76.19	1,733	36.57
Millet.....	13657	6.16	2.03	2.78	.27	13.25	76.60	1,789	34.90
Kafir.....	12302	2.08	2.33	2.14	.51	13.69	79.25	1,819	.....
Milo.....	12304	1.73	2.18	1.98	.51	13.53	80.07	1,823	.....
Kaoliang.....	12303	1.71	2.19	1.97	.46	13.66	80.01	1,826	35.63
Barley.....	18076	6.17	2.08	3.26	.30	11.50	76.69	1,777	.....
Group 3 (legumes):									
Bean, white.....	13490	7.74	2.70	1.69	.49	15.87	71.51	1,683	.....
Pea, ordinary.....	13491	8.13	2.35	1.70	.35	16.12	71.35	1,697	.....
Chick-pea.....	14821	7.31	2.43	2.34	.41	15.75	71.76	1,726	39.24
Peanut.....	15519	7.78	2.29	13.43	.59	17.38	68.53	2,164	.....
Soy bean.....	13351	7.33	3.10	7.57	.72	19.50	61.78	1,829	.....
Group 4 (by-prod- ucts):									
Bran.....	13349	7.51	2.83	2.33	1.96	14.12	71.29	1,687	37.94
Wheat germ.....	14824	5.73	3.03	4.70	.57	18.00	70.49	1,842	36.86
Cotton seed, treated.....	13346	7.37	3.07	3.76	1.55	22.62	61.63	1,725	.....

TABLE 3.—Analysis of bread, on the 35 per cent water basis.

Variety of flour.	Ash.		Fat.	Fiber.	Protein (Nx 6.25).	Car- bohy- drates.	Calories per pound.	Tex- ture.	Color.
	Total.	Salt- free.							
Group 1 (low protein content):	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>			
Chestnut.....	1.65	0.67	1.57	0.40	8.16	53.22	1,208	84	Gray brown.
Cassava.....	1.55	.52	1.59	.40	7.33	54.13	1,210	95	Light yellow brown.
Banana:									
Unripe.....	1.78	.71	1.40	.28	7.33	54.21	1,204	96	Gray brown.
Ripe.....	1.65	.76	1.20	.29	7.49	54.37	1,210	88	Yellow brown.
Dasheen:									
Unpeeled.....	1.98	1.00	1.12	.54	8.33	53.03	1,189	85	Gray brown.
Peeled.....	2.00	.97	1.21	.50	8.25	53.04	1,191	88	Light gray.
Potato:									
Dried.....	1.95	.95	1.34	.40	9.19	52.12	1,196	88	Light yellow gray.
Flakes.....	1.62	.82	1.57	.42	7.51	53.88	1,208	80	Yellow gray.
Boiled.....	1.92	.92	1.36	.29	8.50	52.93	1,200	95	Very grayish.
Starch.....	1.45	.28	1.50	.14	6.86	55.06	1,215	98	White.
Sweet potato.....	1.57	.84	1.49	.44	7.33	54.17	1,207	85	Gray brown.
Group 2 (grains and cereals):									
Spring wheat.....	1.28	.31	2.08	.13	8.74	52.77	1,223	99	Creamy.
Yellow corn:									
Raw.....	1.40	.38	2.06	.21	8.02	53.31	1,227	95	Yellow.
Parched.....	1.35	.40	2.01	.32	8.19	53.13	1,224	94	Dark yellow brown.
Steamed.....	1.34	.40	2.48	.26	8.09	52.83	1,237	96	Yellow.
White corn:									
Raw.....	1.41	.40	1.89	.22	8.24	53.24	1,223	95	Gray tint.
Parched.....	1.39	.40	2.15	.31	8.17	52.98	1,227	96	Light yellow brown.
Steamed.....	1.28	.40	2.37	.24	8.22	52.89	1,237	97	White.
Rice:									
Polished.....	1.31	.29	1.29	.15	8.43	53.82	1,212	96	Grayish.
Brown.....	1.39	.42	1.98	.17	8.37	53.09	1,227	94	Pale yellow brown.
Buckwheat.....	1.36	.40	1.21	.19	8.22	54.02	1,220	84	Light gray.
Rye (1.1 basis).....	1.42	.49	1.35	.31	9.50	52.42	1,209	96	Slightly grayish.
Oatmeal.....	1.51	.57	2.87	.33	9.78	50.51	1,242	98	Yellow gray.
Feterita:									
Clear.....	1.36	.42	1.38	.30	9.79	52.17	1,211	85	Brown.
Patent.....	1.35	.41	1.38	.21	8.74	53.33	1,212	88	Gray.
Millet.....	1.40	.39	1.92	.19	9.18	52.31	1,225	97	Light yellow brown.
Kafir.....	1.55	.48	1.42	.34	9.09	52.60	1,206	97	Brownish gray.
Milo.....	1.44	.48	1.31	.34	8.94	52.97	1,207	98	Yellow gray.
Kaoliang.....	1.45	.51	1.30	.31	9.03	52.91	1,208	96	Red brown.
Barley.....	1.44	.42	2.25	.21	7.97	53.13	1,232	97	Gray.
Group 3 (legumes):									
Bean, white.....	1.90	.86	1.19	.34	11.09	50.48	1,201	84	Yellow.
Pea, ordinary.....	1.66	.67	1.20	.25	11.40	50.49	1,201	79	Yellowish.
Chick-pea.....	1.70	.72	1.64	.29	11.05	50.32	1,211	94	Pale yellow.
Peanut.....	1.61	.62	9.45	.42	12.25	41.26	1,394	98	Yellow brown.
Soy bean.....	2.17	1.17	5.31	.50	13.70	43.32	1,283	85	Rich yellow.
Group 4 (by-products):									
Bran.....	1.96	1.17	1.64	1.38	9.92	50.10	1,186	92	Gray brown.
Wheat germ.....	2.08	1.20	3.24	.40	12.41	46.87	1,238	86	Yellow brown.
Cottonseed, treated.....	2.15	1.23	2.64	1.08	15.87	43.26	1,211	85	Dark brown.
Soy-bean oil cake.....	2.19	1.32	3.84	.52	14.90	42.25	1,224	.....	

TOTAL ASH.

The breads show a wide variation in the total ash content, from 1.28 to 2.19 per cent, on the basis of 35 per cent moisture. The samples having a total ash content lower than 1.50 per cent include bread made from wheat flour alone, and that from potato starch, as well as the bread from corn, rice, buckwheat, rye, barley, millet, and grain sorghums. Among the breads with an ash content above 1.75 per cent are those made from unripe bananas, dried and boiled potato, dasheen, soy bean, bran, and wheat germ. The lowest total



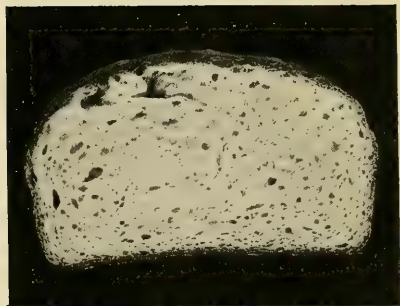
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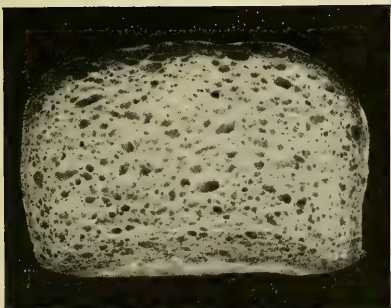
CASSAVA.



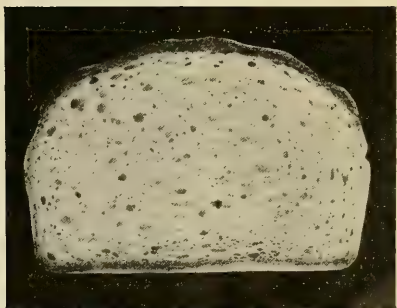
BANANA, UNRIPE.



BANANA, RIPE.



DASHEEN, UNPEELED.

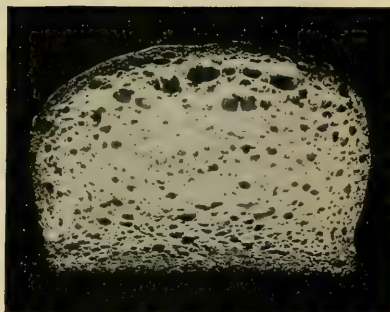


DASHEEN, PEELED.

BREADS FROM WHEAT-FLOUR SUBSTITUTES OF LOW PROTEIN CONTENT (GROUP 1).



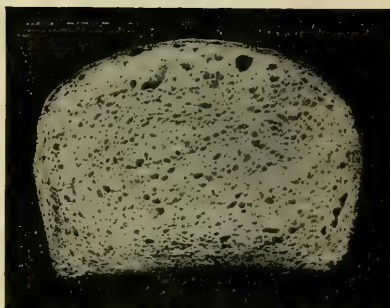
POTATO, DRIED.



POTATO FLAKES.



POTATO, BOILED.



POTATO STARCH.

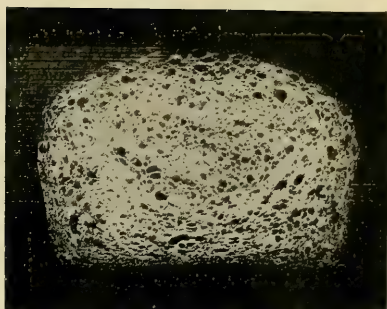


SWEET POTATO FLOUR.

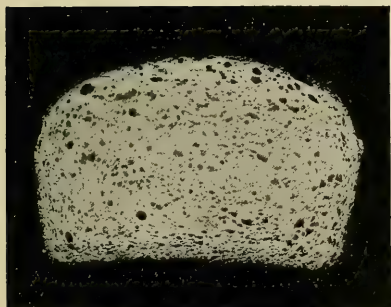
BREADS FROM WHEAT-FLOUR SUBSTITUTES OF LOW PROTEIN CONTENT (GROUP 1).



SPRING WHEAT.



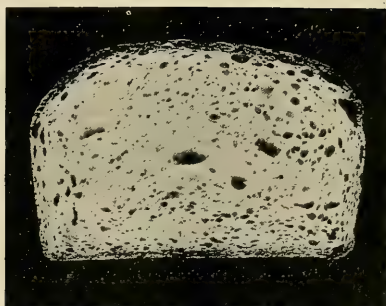
YELLOW CORN MEAL.



WHITE CORN MEAL.

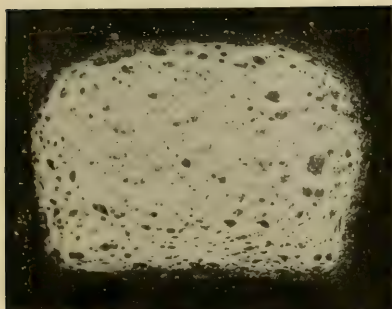


RICE, POLISHED.



RICE, NATURAL BROWN.

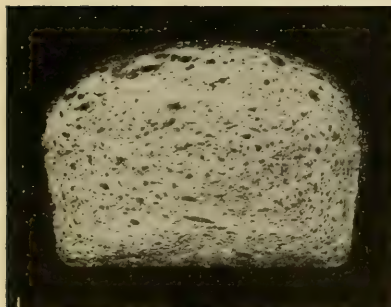
BREADS FROM GRAINS AND CEREALS (GROUP 2).



BUCKWHEAT.



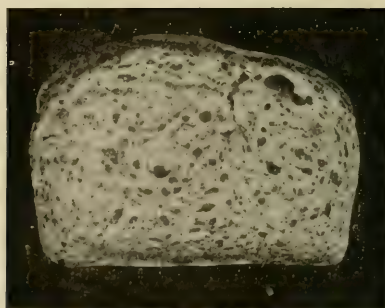
RYE.



OATMEAL.



FETERITA (CLEAR).

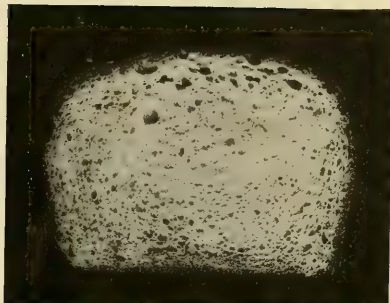


FETERITA (PATENT).

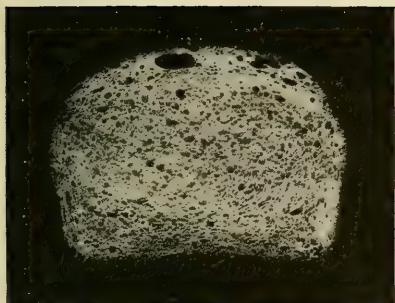
BREADS FROM GRAINS AND CEREALS (GROUP 2).



MILLET.



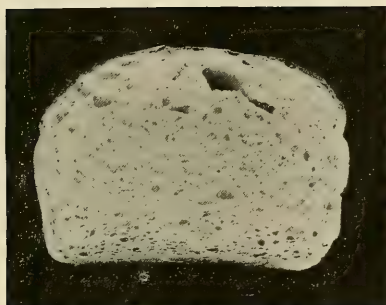
KAFIR.



MILO.



KAOLIANG.



BARLEY.

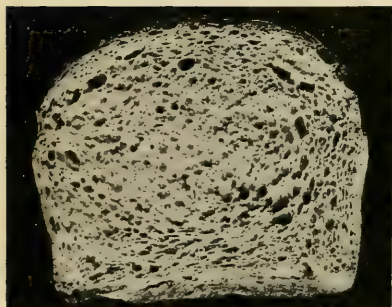
BREADS FROM GRAINS AND CEREALS (GROUP 2).



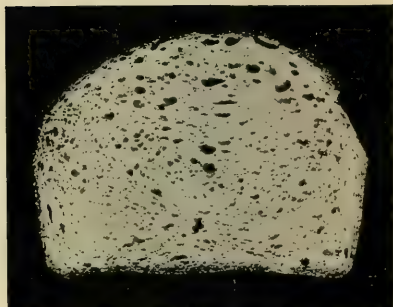
BEAN, WHITE.



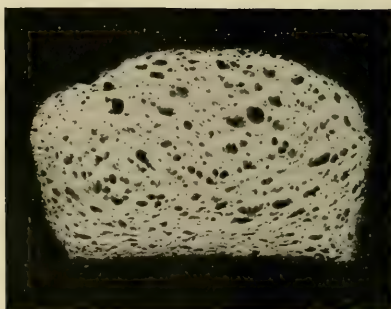
PEA, ORDINARY.



CHICK-PEA.



PEANUT MEAL.



SOY BEAN.

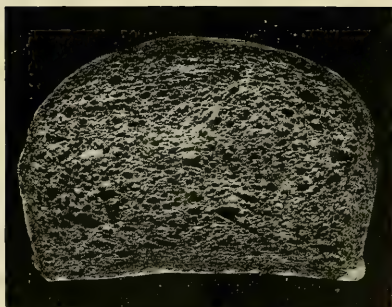
BREADS FROM LEGUMES (GROUP 3).



BRAN.



WHEAT GERM.



COTTONSEED.

BREADS FROM BY-PRODUCTS (GROUP 4).

ash content is found in wheat bread and in bread containing polished rice or starch as an admixture. The breads made from soy bean, wheat germ, and bran had the highest ash content.

SALT-FREE ASH.

In making all of the breads, salt, equivalent to 1.5 per cent of the total flour, was added. If only the total ash content, which includes the added salt, were considered, it might seem that little difference exists in the ash contents of the various breads. For example, the total ash content of the bread made from polished rice flour is approximately the same as that of bread from the brown rice flour, being 1.31 and 1.39 per cent, respectively. Quite different results are given, however, when the ash content is calculated on the salt-free basis. In that case, it is apparent that the polished rice bread could not have more than 0.30 per cent salt-free mineral constituents, while the bread from the natural brown rice would have not less than 0.42 per cent. It is seen also that while wheat-flour bread contains about 0.31 per cent of salt-free ash, bran bread contains 1.17 per cent, almost four times as much.

With the exception of that made from starch, the breads of group 1 are fairly high in salt-free ash. With the exception of that made from barley, rye, oatmeal, and the grain sorghums, the breads of group 2 are generally low in salt-free ash. The breads of group 3 have about the same salt-free ash content as those of group 1. The breads of group 4 and bread from soy-bean flour (group 3) have a very high salt-free ash content, containing about four times as much as the wheat-flour bread, an increase of approximately 300 per cent.

FAT.

The fat content varies from about 1.1 per cent to over 9 per cent. None of the breads of group 1 (those of low protein content) contains much fat. The bread from oatmeal contains almost 3 per cent of fat; that made from wheat-germ flour, a little over 3 per cent; that from soy-bean flour, almost 4 per cent; and that from crushed peanuts (roasted, but not previously pressed), almost 9.5 per cent. The apparent discrepancy in the fat contents of the various breads is due to the fact that, although no fat or shortening was added to the dough, a small amount of shortening was always used on the hands in handling the dough. The amount of shortening thus added to the bread was indefinite, depending upon the character of each individual dough.

FIBER.

The fiber content is very high in the bread made from bran, while in breads made from soy-bean, dasheen, potato, cassava, chestnut, wheat-germ, and peanut flours it is moderately high. In all other

bread is comparatively low. The fiber content is much higher in bran than in any of the other substitutes used.

PROTEIN.

The average protein content ($N \times 6.25$) of the breads belonging to group 1 is less than 8 per cent; of breads belonging to group 2, it is about 8.8 per cent; of those belonging to group 3, it is about 11.9 per cent; while for breads belonging to group 4, it is 12.7 per cent. This protein content varies from less than 7 per cent, in the case of potato-starch bread, to over 15.8 per cent in the case of cottonseed bread. Other breads showing a high protein content are those made from legumes and wheat germ. Breads made with rye, feterita (clear grade), and oatmeal flours are appreciably richer in protein than standard wheat bread. All the breads in groups 3 and 4 are much richer in protein than is the wheat bread. Of group 1, only the bread made from potato flour is richer in protein than all-wheat bread. This, however, was due to the fact that the potatoes used for this experiment happened to be particularly low in starch and high in protein, which would not necessarily be true with potatoes grown in every section of the country.

CALCULATED CALORIC VALUE.

The average number of calories per pound does not differ very much in the various groups of bread. Because of their comparatively high fat content, breads made from peanut and soy-bean flours show a relatively large number of calories per pound, being 1,394 and 1,283, respectively. The bread from oatmeal flour contains 1,242 calories, and that from wheat germ, 1,238 calories per pound. The lowest figures for the caloric value are found among the samples of group 1, and in the case of the bran bread. Bran bread owes its low caloric value to its high fiber or cellulose content. With the possible exception of bread made from peanut, oatmeal, wheat-germ, and soy-bean flours, all of which substitutes contain a large amount of fat, the caloric value of all the breads analyzed is about the same.

TEXTURE, TASTE, AND GENERAL APPEARANCE OF BREAD.

Several of the breads of group 1 have a remarkably fine texture and general appearance. They comprise those made from potato starch, boiled potato, unripe banana, and cassava flour. Those which deserve special attention for their fine flavor are the breads made from chestnut flour, which is rich, nutty, and very agreeable, and from boiled potatoes. The potato bread has the further merit of lending itself well to reheating several days after it has been baked, because it remains moist longer than most other breads. The sweet-potato bread, when made with the usual proportion of sugar, has a

very agreeable, slightly sweetish flavor. Bread made from ripe banana flour also has a sweetish, agreeable, and very characteristic taste, and requires no sugar in its preparation. That made from dried potato flour has a decided potato taste, which makes it much less appetizing than that made from the boiled potato.

Practically all of the breads of group 2 have a very good flavor, although not so marked or characteristic a one as in the case of some of the breads of group 1. The most pronounced flavor was noted in the bread made from rye, from buckwheat, from yellow corn meal and from the sorghum grains. In all other cases the flavor was good, without being too pronounced. The texture of the breads of group 2 ranks very high, several reaching a grade of 95 or over on a standard of 100 for a perfect loaf.

In group 3, the peanut bread easily ranks first both in flavor and in texture. The bread from chick-pea flour is very attractive, being remarkable for its volume and texture, while in taste it is not noticeably different from good wheat bread. Bread made from the Mammoth yellow variety of soy bean has a characteristic beanlike and agreeable flavor, but is not especially good in texture. The bread made from the ordinary dried bean also possesses a characteristic beanlike flavor, which is less marked when the meal is cooked before being used. Bread from dried pea flour has a very agreeable taste.

Every bread of group 4 has a marked flavor peculiar to itself. Bran bread naturally has a characteristic "branny" flavor, which to many is very agreeable. Its color is dark, and its texture fair. The flavor of the wheat-germ bread, while decidedly characteristic, is not unpleasant. It also is dark in color, and does not have a very good texture. Cottonseed-meal bread, even though it contains but 15 per cent of cottonseed meal, has a decided flavor and dark color, although its texture is fairly good.

SUMMARY.

From the salt-free ash determinations it is apparent that all breads containing wheat-flour substitutes (except when starch and rice flour are used) are richer in mineral matter than is wheat-flour bread.

The differences in the fat content of the various breads analyzed are significant only when materials such as the soy-bean or peanut meal (unpressed) are used. The calculated caloric value of the various breads is also so nearly the same that, in general, it will make comparatively little difference, in computing a day's ration on the basis of calories, which bread is taken.

Far more significant is the difference in the protein content. From a value of less than 7 per cent (where starch was used) to one closely approaching 15 per cent (soy-bean bread) is a wide range.

The ideal color of the crumb of wheat-flour bread is creamy. With the exception of breads made with cooked Irish potatoes, polished rice, white corn meal or corn flour, and the pure starches, the color of the mixed breads partakes more or less of the color characteristic of the substitute. Sweet potato and soy-bean meal yield a yellow loaf; banana flour, dasheen, milo, ordinary dried beans, etc., a gray; while many others produce a bread more or less gray brown.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO BREADSTUFFS.

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- Special Flask for Rapid Determination of Water in Flour and Meal. (Department Bulletin 56.)
- Importance and Character of Milled Rice Imported into United States. (Department Bulletin 323.)
- Alaska and Stoner or Miracle Wheats. (Department Bulletin 357.)
- Intrinsic Value of Grain, Cottonseed, Flour, and Similar Products, Based on Dry-Matter Content. (Department Bulletin 374.)
- Experiments with Marquis Wheat. (Department Bulletin 400.)
- Improvement of Ghirka Spring Wheat in Yield and Quality. (Department Bulletin 450.)
- Experiments with Spring Cereals at Eastern Oregon Dry-Farming Substation, Moro, Oregon. (Department Bulletin 498.)
- Characteristics and Quality of Montana-Grown Wheat. (Department Bulletin 522.)
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- Experiments With Durum Wheat. (Department Bulletin 618.)
- The Chemical Analysis of Wheat-Flour Substitutes and of the Breads Made Therefrom. (Department Bulletin 701.)
- Marquis Wheat. (Farmers' Bulletin 732.)
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- Graham Flour, Study of Physical and Chemical Differences Between Graham Flour and Imitation Graham Flours. (Bureau of Chemistry Bulletin 164.) Price, 10 cents.
- Studies on Digestibility and Nutritive Value of Bread at Maine Agricultural Experiment Station. 1899-1903. (Office of Experiment Stations Bulletin 143.) Price, 5 cents.
- Studies of Digestibility and Nutritive Value of Bread and Macaroni at University of Minnesota. 1903-1905. (Office of Experiment Stations Bulletin 156.) Price, 15 cents.
- Course in Cereal Foods and Their Preparation, for Movable Schools of Agriculture. (Office of Experiment Stations Bulletin 200.) Price, 10 cents.
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- Handling Wheat from Field to Mill. (Bureau of Plant Industry Circular 68.) Price, 5 cents.
- Method for Determination of Specific Gravity of Wheat and Other Cereals. (Bureau of Plant Industry Circular 99.) Price, 5 cents.
- Commercial Stocks of Wheat and Flour in United States, Aug. 31, 1917. (Secretary's Circular 100.) Price, 5 cents.
- Hard Wheats Winning Their Way. (Separate 649 from Year Book 1914.) Price, 10 cents.



UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 702

Contribution from the Bureau of Chemistry
CARL L. ALSBERG, Chief



Washington, D. C.

September 12, 1918

EFFICIENCY OF COMMERCIAL EGG CANDLING.

By M. K. JENKINS, *Assistant Bacteriologist*, assisted by C. A. BENGTSON, *Investigator in Egg Handling*. Prepared under the direction of M. E. PENNINGTON, *Chief, Food Research Laboratory*.

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PURPOSE OF INVESTIGATION.

It is common knowledge among those buying and selling eggs that grading by the candle is not an absolutely dependable method for the separation of good and bad eggs. As it is the best method known for determining the quality of eggs in the shell, however, it is important to learn its degree of efficiency. This bulletin aims to show the effectiveness of commercial candling in detecting different kinds of good and bad eggs, as well as the variations in efficiency of different candling forces. In a previous publication,¹ prepared as a guide to beginners wishing to learn how to candle eggs, detailed descriptions, accompanied in many instances by illustrations, are given of the different types of good and bad eggs of common occurrence. The classifications and descriptive terms given there are used in this publication.

The purpose of the investigation here reported, then, may be summarized as follows: To find (1) the relative error in the candling of different types of good and bad eggs; (2) the relation of the quality

¹ U. S. Dept. Agr. Bul. 565.

of eggs to accuracy in candling; (3) the relative occurrence of bad eggs not to be found by candling; (4) the comparative degree of accuracy of skilled and unskilled candling crews.

PLAN AND SCOPE OF INVESTIGATION.

The investigation was carried on in commercial packing houses located in the Middle West and in distributing houses in the East. During warm weather the eggs under observation were kept in chill-rooms, according to commercial practice, at a temperature of 32° to 40° F., from the time of receipt until the time of candling. This chilling serves to check deterioration and to restore to some extent the natural firmness of the egg substance. For grading, the eggs were removed to candling rooms which were refrigerated to a temperature of 50° to 55° F.

After the eggs had been candled they were opened and graded in accordance with the standards for the preparation of frozen and dried eggs. The number of bad eggs not detected by candling was determined by observing the appearance and odor when opened in glass cups. The conclusions reached in this study were drawn from eggs so handled, which had been graded by commercial candlers according to trade routine. It was the endeavor to grade as edible all eggs with whole yolks which were not seeping, not heavily mottled, nor stuck to the shell, and which contained neither blood nor visible mold infection. Out of the shell an egg was graded as edible if the yolk was whole, the white clear and not colored, and the odor good. If the yolk membrane did not break until the egg was dropped in the grading cup, it was considered edible. The usual speed of candling was not changed, because it was desired to determine the accuracy of the process under commercial conditions.

The eggs rejected by the candlers as unfit for food purposes were critically recandled to find any good eggs that might be present and the reason for their not being found on the first candling. In cases of doubt the eggs were opened. It was not considered necessary or desirable to check the candling of the unquestionably bad eggs by breaking.

The studies reported were made on 187 cases (30 dozen each) of storage-packed eggs, 170.2 cases of refrigerator or cold-storage eggs, 174.4 cases of breaking stock, and 1,521.7 cases of rejected eggs, that is, "rots and spots." The observations on the storage-packed and refrigerator or cold-storage eggs were made from samples having a comparable history. On arrival in the East of carload shipments of commercial storage-packed eggs, from 8 to 20 cases were examined within a comparatively short period after receipt. About the same number

from each lot were transferred to a commercial cold-storage warehouse, and withdrawn for candling between the early part of November and the latter part of March. The eggs used for these experiments varied in quality from spring firsts and dirty eggs to summer firsts, seconds, and dirty eggs. These eggs were candled by skilled operators in two large concentrating centers in the East. The storage-packed eggs were, therefore, a very fair representation of the various grades of fresh-gathered market eggs.¹ The accuracy of the candling of the breaking stock was observed in several plants in the Middle West and in two in the East. The candling crews varied widely in efficiency. The rejected eggs studied were from both experienced and inexperienced candlers.

RELATION OF QUALITY OF EGGS TO ACCURACY IN CANDLING.

An analysis of the bad eggs found in eggs candled as edible showed the presence of two distinct groups—one consisting of eggs which are commonly recognized by candling, and the other of types which can be detected only out of the shell. The proportion of the first group in eggs candled as edible may, therefore, be used as an index to the accuracy of candling. The ideal to be attained in candling is the elimination of all errors in the grading of those types of eggs which can be identified before the candle.

The accuracy of skilled candlers depends upon the quality and condition of the stock. Generally speaking, the more bad eggs there are present, the greater will be the number missed. This is not always the case, however, because the type of deterioration influences the accuracy of candling. For example, the black and white rots, moldy eggs, and heavily stuck yolks, characteristic of the bad eggs occurring in dirty eggs, are much more readily detected by candling than the light-blood rings, slightly stuck yolks, and partially disintegrated yolks, common in summer stock (Tables 1 and 11).

¹ In this publication the terms "fresh-gathered" and "fresh-marketed" eggs refer to eggs which are marketed without the intervention of cold storage.

TABLE 1.—*Effect of quality of eggs upon accuracy of candling.*

Grade.	Number of cases candled.	Bad eggs per case.			
		Total number.	Detected by can- dling.	Missed by candling.	
				Distin- guishable by can- dling.	Not disting- uishable by can- dling.
FRESH-MARKETED EGGS.					
1914 firsts.					
April.....	19.56	0.85	0.20	0.20	0.45
May.....	19.52	2.86	2.39	.21	.26
June.....	19.23	4.68	4.32	.26	.10
1915 firsts.					
June.....	8.45	7.10	3.43	2.01	1.66
July.....	10.45	17.51	13.11	3.06	1.34
1914 dirty eggs.					
April.....	19.64	5.95	2.65	.91	2.39
May.....	19.52	12.04	9.02	.92	2.10
June.....	18.88	19.58	17.62	1.01	.95
July.....	18.30	25.73	23.11	2.24	.38
1914 seconds.					
July.....	14.57	7.21	5.91	1.16	.14
1915 seconds.					
June.....	8.42	20.90	10.81	4.99	5.10
July.....	10.46	26.72	17.15	4.69	4.88
COLD-STORAGE EGGS.					
1914 firsts.					
April.....	13.95	9.57	6.59	1.30	1.68
May.....	14.91	14.15	10.53	2.28	1.34
June.....	9.75	4.41	3.59	.21	.61
1915 firsts.					
June.....	14.89	23.89	13.43	7.12	3.34
July.....	11.67	33.56	19.89	10.11	3.56
1914 dirty eggs.					
April.....	19.88	16.60	13.28	1.41	1.91
May.....	25.86	28.38	22.55	2.98	2.85
June.....	10.07	23.73	20.78	.99	1.96
July.....	10.22	28.86	27.30	1.56	.00
1914 seconds.					
June.....	15.03	36.20	19.09	10.77	6.34
1915 seconds.					
June.....	10.17	14.75	10.61	3.93	.21
July.....	13.80	32.18	15.65	9.60	6.93

Comparative observations on similar grades of eggs before and after storage showed that the cold-storage or refrigerator eggs were not candled as accurately as the corresponding fresh-gathered eggs (Tables 1 and 11 and fig. 1). As summarized in Table 2, 19.67 per cent of the bad eggs present in the refrigerator eggs were miscandled, as compared with 12.34 per cent in the fresh-gathered eggs. The changes which had taken place in the eggs during holding in cold storage no doubt account for these findings. As an egg ages in cold storage, the opalescent tinge characteristic of the white changes to a

cloudy yellow, and the yolk membrane becomes gradually weaker. The contrast between the white and yolk is thereby reduced, and detection of the condition of the egg by candling is rendered more difficult.

It was observed in the different lots of eggs candled that the number of bad eggs not distinguishable by candling varied to practically the same extent as the bad eggs miscandled (Table 1). As mentioned in connection with the miscandled group, the number present depends very largely upon the

original quality of the eggs. Green-white and sour eggs, two of the important members of this group, are frequently found among eggs with soiled, wet, or broken shells. These two types of bad eggs are caused by bacteria which enter the eggs through the shells.

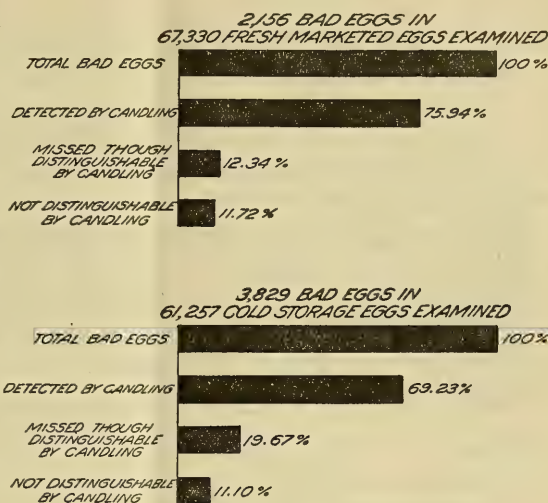


FIG. 1.—Observations on similar grades of eggs candled before and after storage.

TABLE 2.—Efficiency of candling in detecting bad eggs.

Kind.	Num-ber.	Types detected by candling.		Types missed by candling.			
				Distin-guishable by candling.		Not distin-guishable by candling.	
		Num-ber.	Per cent.	Num-ber.	Per cent.	Num-ber.	Per cent.
Bad eggs from 187 cases (67,330 eggs) com- mercial storage packed eggs:							
Black rots.....	340	340	100	0	0		
Heavily stuck yolks.....	122	122	100	0	0		
Moldy eggs.....	232	226	97.41	6	2.59		
Large embryos.....	35	33	94.29	2	5.71		
White rots.....	505	453	89.71	52	10.29		
Slightly stuck yolks.....	169	133	78.70	36	21.30		
Blood rings.....	30	23	76.67	7	23.33		
Mixed rots.....	450	302	67.12	148	32.88		
Bloody whites.....	20	5	25	15	75		
Green whites.....	188					188	100
Eggs with bad odor and normal appear- ance.....	65					65	100
Total.....	2,156	1,637		266		253	
Per cent.....			75.94		12.34		11.72

TABLE 2.—*Efficiency of candling in detecting bad eggs—Continued.*

Kind.	Num- ber.	Types missed by candling.					
		Types detected by candling.		Distin- guishable by candling.		Not distin- guishable by candling.	
		Num- ber.	Per cent.	Num- ber.	Per cent.	Num- ber.	Per cent.
Bad eggs from 170.2 cases (61,257 eggs) refriger- ator or cold storage eggs:							
Black rots.....	431	431	100	0	0		
Heavily stuck yolks.....	130	130	100	0	0		
Moldy eggs.....	810	767	94.69	43	5.31		
White rots.....	355	328	92.39	27	7.61		
Slightly stuck yolks.....	525	213	40.57	312	59.43		
Mixed rots.....	704	453	64.34	251	35.66		
Bloody whites.....	3	2	66.67	1	33.33		
Crusted yolks.....	443	324	73.14	119	26.86		
Frozen yolks.....	3	3	100	0	0		
Green whites.....	294					294	100
Eggs with bad odor and normal appear- ance.....	131					131	100
Total.....	3,829	2,651		753		425	
Percent.....			69.23		19.67		11.10

EFFICIENCY OF CANDLING BAD EGGS IN RECEIPTS.

An analysis was made of the varieties of bad eggs found in the several lots of fresh-gathered and refrigerator eggs given in Table 1. The different kinds of bad eggs detected by candling, the kinds which were miscandled, and those which could be found only when the shell was broken were noted. These observations, covering approximately 357.2 cases candled by experienced candlers in accordance with trade routine, are summarized in Table 2, and given in detail in Table 11. A second series of observations was made on summer breaking stock which included seconds, cracked and dirty eggs, and current receipts. The eggs were candled by the regular candlers, some of whom were experienced and some of whom were not. The types of bad eggs miscandled and the types of bad eggs which could not be found by candling were noted as the eggs were opened in the breaking room (Table 3). At the time that these results were obtained the number of bad eggs, as determined by candling, ranged approximately from 18 to 42 per case. Thirteen types of bad eggs were found, of which all but two could be distinguished by candling, though sometimes they were not.

BAD EGGS DISTINGUISHABLE BY CANDLING.

BLACK ROTS, MOLDY EGGS, AND HEAVILY STUCK YOLKS.

Black rots, eggs having mold spots, and eggs with yolks heavily stuck to the shell are, with few exceptions, readily seen before the candle. Errors in grading these eggs are usually an evidence of care-

lessness. Mold growths may escape notice if the egg is not completely turned before the candle, or if it is covered with the fingers. If the candler does not concentrate his entire attention upon his work he may make the mistake of putting a black rot or some other bad egg in the case for good eggs, or vice versa. The holding of more than two eggs in each hand increases the likelihood of such mistakes. To reduce the chances for these errors the foreman should instruct the new candlers in the proper manipulation of the eggs, and should not permit talking, except about the work, or any other form of distraction during working hours.

In these studies no errors were noted in the placing of black rots or eggs with heavily stuck yolks in the wrong case. That such an error does sometimes happen is proved by observations in egg-breaking rooms where large numbers of eggs are opened. It happens very infrequently, however, in well-regulated candling rooms where the candlers give their entire attention to their work, and do not talk and joke with their neighbors.

TABLE 3.—*Efficiency of candling in detecting bad eggs in breaking stock.*

62,799 eggs (174.4 cases) candled as good.	{	96.73 per cent good eggs.	{	1.44 per cent eggs with adherent yolks.	
		{		2.51 per cent types detectable by candling.	0.38 per cent blood rings.
	{			{	0.40 per cent white rots.
					0.20 per cent mixed rots.
					0.06 per cent moldy eggs.
					0.03 per cent bloody whites, heavily mottled yolks, and eggs with large embryos.
	3.27 per cent bad eggs.	0.76 per cent types not detectable by candling.		0.52 per cent eggs with bad odors.	
			0.24 per cent eggs with green whites.		

In Tables 2, 3, and 11 it will be seen that few moldy eggs were misgraded. The six that were miscandled as given in the first part of Table 2 had moldy, free-moving yolks, an unusual form of mold infection. The 43 eggs reported in the last part of Table 2 contained inside the shell small, watery, gelatinous mold spots which were not always distinguishable or seen only indistinctly through the shell before the candle. Those mentioned in Table 3 were cracked eggs with moldy shells and normal contents which are more readily seen by ordinary inspection than by candling. The darkness of the candling room was the probable cause of this mistake. An opening in the lower part of the candle to throw light on the eggs in the cases below helps to reduce such errors.

MIXED AND WHITE ROTS.

Mixed and white rots are common types of bad eggs. Mixed rots, which are an early stage of white rots, are caused by the disintegration of the yolk. In this study of the accuracy of candling extremely weak eggs, eggs with seeping yolks, with or without mottled areas, and eggs with broken yolks will be considered in the

mixed rot class, since all represent the first stages of yolk deterioration. The color before the candle of mixed and white rots, like that of fresh eggs, depends on the color of both the shell and the yolk. A light yellow yolk in a white shell has a pale yellow appearance before the candle, and a brown shell or a dark yellow yolk in a white shell gives a reddish color. Brown shells or pale yolks in white shells are factors which reduce the contrast between white and yolk. The candler may very easily confuse the general yellow or pinkish color of good eggs with that of a mixed or white rot if he does not study the condition of the yolk and allow for the color of the shell. Even with close examination it may not be possible always to distinguish between a whole and a broken yolk. In some instances the entire yolk membrane may be so weak that the outline of the yolk changes when the egg is turned, making it difficult to determine whether it is whole or not. In other cases the presence of the yolk in the white, due to seepage, can not be detected because of the opacity of the shell. Again the white may be so firm that it tends to prevent the spreading of the yolk material, even though the yolk sac may be ruptured. These different forms of yolk deterioration are readily recognized when the egg is opened.

Table 2 shows that out of 187 cases of eggs 505 white rots and 450 mixed rots were found, of which 89.71 per cent and 67.12 per cent, respectively, were detected by commercial candling. The proportion of these eggs miscandled in refrigerator eggs was practically the same (Table 2). As white rots are an advanced form of mixed rots, and present more distinctive characteristics before the candle, it is to be expected that the error in candling would be less. The data given in Table 3 further confirm these findings.

EGGS WITH SLIGHTLY STUCK YOLKS.

The egg with the slightly stuck yolk, representing one of the most common types of deterioration in summer, is very frequently miscandled. A pale yolk or a brown shell increases the difficulty of detection. In addition, when the yolk is stuck by a small area only it may sway back and forth so readily that it is difficult to determine whether it is free or adherent. If the turning during the candling tears the yolk from the shell it may be so slightly broken and the white so firm that it is almost impossible to determine whether the yolk is whole or broken. The yellow stain on the shell marking the place where the yolk was stuck and which is characteristic of this egg when out of the shell is not always visible before the candle.

Checking the decision made by candling with the appearance of the egg out of the shell is one of the most effective means of becom-

ing skilled in the grading of eggs with stuck yolks. When they are the prevailing type of bad eggs present judgment of grade should be made as far as possible with the first turning of the egg before the candle, because further rotation often serves to make detection more difficult. The distinguishing feature to be looked for is the adhering portion of the yolk.

In the lots of eggs reported in Table 2 from 40.57 to 78.70 per cent of the eggs with slightly adherent yolks were found by candling. In the summer breaking stock and refrigerator eggs it was the leading type of eggs miscandled (Tables 2 and 3).

BLOOD RINGS AND LARGE EMBRYOS.

Fertile eggs containing blood rings occur most frequently when the weather is sufficiently warm to cause development of the germ spots. In the early stages when there is but a mere trace of blood present, it is not always easy to find them by candling, especially if they happen to be inclosed in a brown shell. In the later stages when the yolk is weak, the blood ring may be covered with a fold in the yolk, and thus escape detection. The blood ring is best seen if the egg is turned gradually before the candle so that the yolk revolves slowly, allowing the germinal spot and the surrounding area which has a rosy appearance to float near the shell. When the yolk is near the shell a darkened area should be looked for, and, if this is present, it should be examined carefully for dark or red streaks or a ring. A candle with a bright light is absolutely necessary if small blood rings are to be found. When the blood-veined area has developed to the size of a 5-cent piece or larger its detection is ordinarily a simple matter.

The ease with which serious errors in failing to find blood-ring eggs may occur was well illustrated in one house under observation where careless candlers working with dimly lighted candles put 3.4 per cent of such eggs into seconds intended to be edible. In the summer breaking stock as many blood rings as white rots were misgraded (Table 3). The use of a candle with a weak light or with an opening which is too large results in failure to detect these eggs.

EGGS WITH BLOODY WHITES.

Eggs with bloody whites are caused by the rupture of the blood vessels during the passage of the egg down the oviduct. Their occurrence is comparatively rare, for out of 357.2 cases of eggs studied but 23 were found. Of these 7 were found by candling and the balance by breaking. These eggs are not readily seen in the shell because the pinkish tint due to the presence of blood is very nearly the same as that given by a brown shell or a white shell con-

taining a dark-yellow yolk. When blood clots are present, as is frequently the case, they serve to make identification easier. If eggs with diffused blood occurred more frequently, candlers would become more familiar with their characteristics, and a larger percentage would no doubt be recognized by candling.

BAD EGGS NOT DISTINGUISHABLE BY CANDLING.

EGGS WITH ABNORMAL ODORS.

Eggs with abnormal odors, including sour and musty eggs, constituted a large proportion of the inedible eggs which could not be detected by candling (Tables 2 and 3). The well-known musty egg in many instances presents an exceptionally fresh appearance before the candle and out of the shell. Only occasionally is the odor so strong that it can be noticed before the egg is opened.

The egg with the sour odor frequently shows such extensive physical deterioration that it can be recognized as a white or mixed rot on candling. If, however, disintegration has not progressed to such an extent, it can not be detected except by the sense of smell when the egg is broken. Bacteriological studies show that the characteristic odor is not produced until the bacteria have developed in large numbers.¹ Eggs having ammoniacal or fishy odors due to bacterial deterioration are not uncommon, and, as in the case of sour eggs, physical changes may not be apparent until an enormous number of bacteria have accumulated. These, too, are identified by the abnormal or characteristic odor apparent when the eggshell is removed.

Because their shells are porous, eggs absorb odors easily from surrounding materials. Very frequently eggs have the odor of moth balls, kerosene, carbolic acid, mold, and damp fillers and flats. Some of the absorbed odors disappear after the egg has been opened, but others remain permanently. Eggs which retain abnormal odors are rejected, and, since the odor is such an important factor in grading eggs out of the shell, great care must be exercised in grading when an odor is present.

EGGS WITH GREEN WHITES.

Eggs with green whites constituted a large proportion of the bad eggs not discernible by candling. They are recognized by the green color of the white when the egg is opened. This color is not present until the specific organisms which produce it have multiplied enormously. Because these eggs are so heavily infected and are chemically decomposed, care should be taken to eliminate them from food products.

¹ U. S. Dept. Agr. Bul. 51, page 61.

EFFICIENCY OF CANDLING REJECTS.

Just as the bad eggs found in eggs candled as good were studied to determine the reason for their not being discovered, the good eggs found in eggs candled as bad were subjected to critical tests to find out why they were miscandled. In this work attention was directed more to the characteristic appearance before the candle, than to the condition found when breaking the egg out of the shell. The latter method was resorted to only when there was doubt concerning the quality of the egg as ascertained by candling.

To determine how many good eggs were placed with the bad eggs and what the characteristics of these eggs were, 12,024 rejected eggs, mostly from inexperienced candlers, were critically recandled. Among the bad eggs were found 19.9 per cent good eggs, divided between six main groups, namely, brown eggs, hatch-spot and weak eggs, eggs with the yolk floating near the shell, eggs with olive-green yolks, good eggs with broken air cells, and good eggs included because of carelessness (Table 4). As the causes of error for the six types of eggs are different, each will be discussed separately.

TABLE 4.—*Kinds of good eggs in eggs candled as bad and doubtful (determined by recandling).*

12,024 eggs (33.4 cases) candled as bad and doubtful.	80.1 per cent bad eggs.	6.3 per cent eggs with brown shells.
	19.9 per cent good eggs...	5.6 per cent heated eggs, including hatch-spot and weak eggs.
		3.1 per cent eggs with the yolk floating near the shell.
		2.1 per cent eggs with olive-green yolks.
		1.4 per cent good eggs, probably due to carelessness.
		1.2 per cent eggs with movable air cells.
		0.2 per cent eggs with dirty shells, double yolks, and leakers.

GOOD EGGS IN REJECTS.

BROWN EGGS.

Brown eggs constituted about one-third of the good eggs not detected by candling (Table 4). The brown shell, in giving the egg a general reddish color before the candle, reduces the contrast between the white and yolk. This difference is due to a lesser degree of transparency in the case of the eggs with brown shells. The darker the color of the shell, the more difficult it is to judge the condition of the contents. The bad eggs with which good eggs in brown shells may be confused are mainly mixed and white rots, eggs with slightly stuck yolks, blood rings, and eggs with blood in the whites. A candle with a bright light and with an opening of the proper size, so that no rays of light escape around the egg, is a prerequisite for the satisfactory grading of these eggs. With a little study and experience there should be small difficulty in detecting any except those with extremely dark shells. An egg with a stained shell is sometimes miscandled because the appearance before the

candle gives a false impression of the condition of the contents. The inspection of the egg without the aid of the candle is usually sufficient to correct this delusion.

HEATED EGGS INCLUDING HATCH-SPOT EGGS AND WEAK EGGS.

Weak eggs and hatch-spot eggs are characteristic of summer seconds. They formed over 5 per cent of the good eggs found in the rejects. The warmth of the summer weather enables the native enzymes to weaken the structure of the egg, and, if the egg happens to be fertile, a partial development of the embryo also occurs. Because the yolk of an egg with a weak vitelline membrane flattens out with each turn before the candle, it is not always easy to determine whether or not the yolk is intact. If the yolk besides being weak shows signs of incubation, it is necessary to determine whether blood is present. A dark shell or a white shell inclosing a light-colored yolk also makes for inaccuracy. If new candlers are not instructed they invariably throw away hatch-spot eggs because of the darkened area on the yolk.

EGGS WITH YOLKS FLOATING NEAR SHELLS.

Eggs with the yolk floating near the shell are frequently mistaken for eggs with slightly adherent yolks, if the candler does not invert each egg to see whether the yolk will move away from the shell. It sometimes happens that the jar of placing an egg with a slightly stuck yolk in the case dislodges the yolk so that upon recandling it has the appearance of a good egg. About 3 per cent of the good eggs found on recandling rejects were eggs with yolks resting near the shell.

TABLE 5.—*Accuracy of recandling rejects.*

House.	Number of eggs broken.	Total bad eggs found.	
		Average per case.	Per cent.
Bad eggs found on breaking good eggs recandled from rejects:			
D.....	281	33.2	9.24
I (period 1).....	1,473	33.7	9.36
I (period 2).....	971	77.85	21.63
J.....	1,152	37.5	10.41
Total.....	3,877		
Average.....		45.9	12.75
Good eggs left in rejects after recandling:			
D.....	720	13	3.5
E.....	3,600	24.9	6.9
I (period 1).....	3,600	2.5	.7
I (period 2).....	3,600	2.2	.6
Total.....	11,520		
Average.....		11.8	3.3

EGGS WITH OLIVE-COLORED YOLKS.

Eggs with olive-colored yolks, caused probably by the character of the food eaten by the hen, are discarded by inexpert candlers because of the yellowish-green appearance of the yolk before the light. This egg is normal in taste, odor, and appearance except for the greenish tinge in the yolk. It contains no bacteria and shows no chemical deterioration. Such eggs formed 2.1 per cent of the rejects.

EGGS WITH MOVABLE AIR CELLS.

Eggs in which the two shell membranes have been separated or broken so that the air cell changes its location as the egg is turned before the candle are frequently graded as bad because of the difficulty of seeing the condition of the yolk. This difficulty is increased if the yolk is weak or the shell is brown. A quick twirl of the egg before the candle to throw the yolk near the shell aids in identification. Eggs with movable air cells constituted 1.2 per cent of the rejects studied.

ACCURACY IN RECANDLING REJECTS.

In order to test the accuracy of the recandling of the rejects both eggs salvaged as good and eggs rejected as bad were broken and their condition noted.

TABLE 6.—*Kinds of bad eggs found on breaking eggs recandled from rejects as good.*

525 eggs candled from rejects as good.	{	421 good eggs.	{	13 mixed rots.		
		{		33 eggs miscandled.....	11 white rots.	
				{	71 eggs not distinguishable	7 eggs with slightly stuck yolks.
					by candling.	2 moldy eggs.
				47 eggs with green whites.		
				24 eggs with bad odors.		

The percentage of bad eggs found in 3,877 eggs recandled from rejects as good averaged 12.75 per cent, and showed wide variations for the different lots of eggs observed (Tables 5 and 8). These numbers are markedly higher than those found in better grades of eggs after candling (Table 1). This difference is to be expected, because the higher the percentage of bad eggs present, the greater are the chances for errors in candling. Besides this factor, there is the increased difficulty of detecting the good eggs mixed with the rejects as compared with better grades of eggs, because they consist of types of eggs set aside by the original candlers as puzzling or impossible to grade. The types of bad eggs rejected during the breaking of 525 eggs recandled from rejects as good are given in Table 6. In plants having an egg-breaking department the eggs salvaged from rejects are broken, the bad eggs eliminated, and the good eggs used for freezing or drying.

On breaking 32 cases of rejects from which the good eggs had been salvaged by recandling, an average of 11.8 good eggs per case were found, and a variation of 2.2 to 24.9 per case for different houses (Table 5). Is it worth while to break the rejects without recandling in order to save any good eggs which may be among them? This question must be answered in the negative for the following reasons: First, the senses of the breakers become so blunted and bewildered by the bad eggs incurred, that it is impossible, even under competent supervision, to accurately separate the good from the bad eggs. Secondly, the heavy contamination resulting from the preponderance of bad eggs precludes the preparation of a wholesome, clean product. Thirdly, the cost of the time consumed in changing and sterilizing apparatus after bad eggs (which operation can not be omitted) would overbalance the value of the good eggs saved.

ACCURACY OF CANDLING CREWS.

The accuracy of the work of different candling crews is influenced by the following factors:

1. The quality of the eggs to be candled.
2. The skill of the individual candlers.
3. The ability of the foreman to grade eggs and to direct a candling force.
4. The enforcement of a system of checking the work of individual candlers.

The accuracy of the candling of seven different crews was determined from the percentage of bad eggs found on breaking summer seconds candled as good, and from the percentage of good eggs recandled by the foreman or inspector from eggs rejected by individual candlers as bad or difficult to grade.

EXPERIENCED CANDLERS VS. INEXPERIENCED CANDLERS UNDER GOOD MANAGEMENT.

Skilled candling is characteristic of crews in the consuming centers, because work is afforded the whole year and because from them the eggs go to the consumer. When the season of production has passed eggs are withdrawn from storage and candled before being placed on the market. Unskilled candling is typical of the producing districts, as the grading of eggs is carried on only during the commercial laying season, which generally lasts about 5 months. The candlers employed in the spring drift into other occupations in the fall and others take their places the following season. The foremen of candling crews in the producing districts are usually experts who have gained their experience through several seasons of candling, either in the producing districts or in the consuming centers.

TABLE 7.—*Accuracy of candling crews.*

House.	Season of observation.	Location.	Candlers.	Eggs candled as edible.						Eggs candled as bad and doubtful.		
				Number of cases observed.	Bad eggs found on breaking.				Number of cases observed.	Good eggs found by recandling.		
					Miscandled.		Not distinguishable by candling.			Number per case.	Per cent.	
												Number per case.	Per cent.	Number per case.	Per cent.
Skilled crew; good management.												
G.....	1914	Consuming center...	Men.....	26.95	5.4	1.5	2.9	0.8				
I.....	1914	do.....	do.....						226.25	7.9	2.2	
K.....	1914	Producing section...	do.....	60.55	6.5	1.8	2.9	0.8	27.35	10.8	3.0	
Unskilled crew; good management.												
D.....	1914	Producing section...	Men.....	28.56	2.5	0.7	0.7	0.2	7.15	66.6	18.5	
E.....	1912	do.....	Women.....	11.40	10	2.8	8.6	2.4	373	59.4	16.5	
F.....	1912	do.....	do.....	5.50	4	1.1	2.2	.6	73.5	39.6	11	
Unskilled crew; poor management.												
D.....	1912	Producing section...	Men.....	7.27	25.9	7.2	4.3	1.2	30	30.2	8.4	
J.....	1914	do.....	Men and women.	34.19	17.6	4.9	2.2	.6	154.9	132.5	36.8	

Where a system of checking the work of unskilled individual candlers was enforced, the number of bad eggs graded by them as good was ordinarily no greater than that found with skilled labor (Table 7 and fig. 2). To accomplish this result with untrained labor the individual candlers were instructed to place all eggs which were difficult to grade with the rejects or in a container by themselves. The rejected eggs from the unskilled crews were recandled by the foreman or another expert, and a record kept of the good eggs thus reclaimed. If an undue number of edible eggs were found, the inspector called the attention of the individual candler to the fact, and gave him the instruction necessary to enable him to avoid future mistakes. The same routine may frequently be followed in the case of skilled labor in order to maintain a high standard of accuracy, and to locate a lack of knowledge on the part of any individual. By this procedure some good eggs were found to be present always in the rejects, especially in those from inexperienced candlers. The reverse should be avoided. From 39.6 to 66.6 eggs per case were salvaged by recandling the rejects from inexperienced candlers thus instructed. If 10 per cent of these eggs were found to be bad on

breaking, the number of good eggs saved would still greatly overbalance the cost of recandling. On the other hand, the results of the recandling of the rejects from experienced candlers showed that

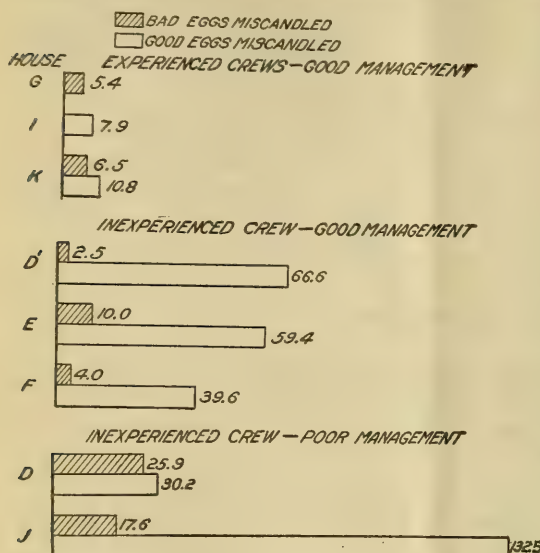


FIG. 2.—Accuracy of candling crews. Data reported as eggs per case.

the value of the good eggs saved did not always pay the cost of the salvaging (Table 8). It will be noted in the table that a larger proportion of the eggs were candled at a profit during the last than during the first period, which fact is accounted for not only by a larger percentage of good eggs, but also by their increased commercial value. In August the wholesale price of eggs was 16 cents, and in November 20 cents per dozen.

TABLE 8.—Comparison of cost of recandling rejects of experienced candlers with value of good eggs salvaged.

Date, 1915.	Cases rejects re- candled.	Good eggs found on recand- ling.	Bad eggs discarded on break- ing.	Good eggs salvaged.		Labor of man recandling.	
Period 1:		Dozen.	Dozen.	Dozen.	Value.	Hours.	Cost.
July 31.....	20	13 $\frac{1}{2}$	1 $\frac{1}{2}$	11 $\frac{1}{2}$	\$1.88	5 $\frac{1}{2}$	\$1.65
August 3.....	20	6 $\frac{1}{2}$	1 $\frac{1}{2}$	5 $\frac{1}{2}$	.91	4	1.20
August 7.....	20	9 $\frac{1}{2}$	2 $\frac{1}{2}$	7 $\frac{1}{2}$	1.15	5 $\frac{1}{2}$	1.65
August 11.....	31	14	1	13	2.08	8	2.40
August 16.....	37	23	1	22	3.52	10	3.00
August 18.....	19 $\frac{1}{2}$	8	$\frac{1}{2}$	7 $\frac{1}{2}$	1.23	6	1.80
Do.....	15.4	14	1 $\frac{1}{2}$	12 $\frac{1}{2}$	2.03	5	1.50
Total.....	162.9	88 $\frac{1}{2}$	8 $\frac{1}{2}$	79 $\frac{1}{2}$	12.80	44	13.20
Average per case.....		6.5 eggs.	0.5 eggs.	6 eggs.	0.08	16 min.	0.08
Period 2:							
November 4.....	8 $\frac{1}{2}$	19 $\frac{1}{2}$	3	16 $\frac{1}{2}$	3.27	3	.90
November 5.....	3 $\frac{1}{2}$	8 $\frac{1}{2}$	1 $\frac{1}{2}$	7 $\frac{1}{2}$	1.55	1 $\frac{1}{2}$	.45
November 6.....	4 $\frac{1}{2}$	5 $\frac{1}{2}$	$\frac{1}{2}$	4 $\frac{1}{2}$	.93	1 $\frac{1}{2}$	.45
November 9.....	9	14	2 $\frac{1}{2}$	11 $\frac{1}{2}$	2.28	2	.60
November 10.....	6	7	3	4	.80	2 $\frac{1}{2}$	.68
November 11.....	8	10 $\frac{1}{2}$	3	7 $\frac{1}{2}$	1.57	3 $\frac{1}{2}$	1.05
November 16.....	6 $\frac{1}{2}$	5 $\frac{1}{2}$	$\frac{1}{2}$	5	1.00	1 $\frac{1}{2}$	.38
November 17.....	5 $\frac{1}{2}$	6 $\frac{1}{2}$	$\frac{1}{2}$	5 $\frac{1}{2}$	1.08	1 $\frac{1}{2}$	.45
November 18.....	6	3 $\frac{1}{2}$	1 $\frac{1}{2}$	2	.40	1 $\frac{1}{2}$	.45
November 19.....	3	2	1 $\frac{1}{2}$	1 $\frac{1}{2}$	.18	$\frac{1}{2}$	.15
Total.....	60 $\frac{1}{2}$	82 $\frac{1}{2}$	17 $\frac{1}{2}$	65 $\frac{1}{2}$	13.06	18 $\frac{1}{2}$	5.56
Average per case.....		16.5 eggs.	3.5 eggs.	13 eggs.	.22	18.42 min.	.09

TABLE 9.—Accuracy of individual inexperienced candlers at E House, determined by recandling breaking stock and rejects.

Candler No.	Number of cases of rejects candled.	Number of cases of good eggs recandled.	Good eggs in rejects.	Bad eggs in good eggs.
			<i>Per cent.</i>	<i>Per cent.</i>
1.....	16	20.4	8.7	0.5
2.....	8	16.4	9.3	.4
3.....	29	24.0	11.1	.7
4.....	19	22.8	11.8	.7
5.....	15	20.8	13.9	.5
6.....	28	22.4	15.1	1.2
7.....	18	22.0	15.4	.9
8.....	26	16.4	16.6	.8
9.....	5	5.8	16.7	.2
10.....	40	22.8	17.3	.6
11.....	38	21.6	17.7	.9
12.....	19	12.4	18.0	.7
13.....	37	22.8	18.9	.3
14.....	30	10.8	19.4	.8
15.....	15	10.8	21.3	.7
16.....	30	16.8	34.0	1.0
Total.....	373	289		
Average.....			16.5	.7

Even though the rejects from experienced candlers may sometimes be recandled at a loss, it is worth while occasionally to discipline the candlers to accurate work. For example, on November 4 an average of 3 dozen good eggs per case was found by recandling the rejects of an experienced force. After the results were made known to the crew the number of good eggs miscandled was markedly reduced (Table 8). Variations in the accuracy of inexperienced candlers working under the direction of a skilled foreman are given in Tables 9 and 10.

INEXPERIENCED CREWS UNDER POOR MANAGEMENT.

The results given in Table 7 and figure 2 show what may be expected when inexperienced workers are allowed to grade eggs without intelligent supervision.

The candling crew of D House in 1912 was governed by an incomplete system of inspection. The rejects were recandled by the foreman to save the good eggs, but the pails of goods eggs going to the breaking room were not identified, so that errors in candling could be traced to the original candlers. The candlers, knowing that their rejects only were being examined, became so cautious about discarding good eggs that they erred in the other direction, and put an undue number of bad eggs into the pails of eggs for the breaking room. As no discipline was enforced the employees continually talked with each other instead of concentrating their attention upon their work.

A combination of factors led to inaccurate work in J House. No foreman was in direct charge of the work; the candlers were inexperienced; the eggs were of low quality; and practically no system

of checking the work of individual candlers was in operation. The one expert in the force was delegated to recandle the rejects, to reclaim any good eggs which might be present. He did not instruct the candlers regarding their mistakes in grading. Consequently their work did not improve with added experience.

ESSENTIALS OF GOOD MANAGEMENT.

From the foregoing it may be concluded that for the preparation of standard grades of food eggs a rigid system of inspection of the work of individual candlers must be enforced, particularly when a force of inexperienced candlers is employed. This system should include not only the recandling of the rejects, but also daily representative portions of the eggs graded as good. If the plant is equipped with an egg-breaking room, the accuracy of the candling of the breaking stock can be easily checked as the eggs are opened. To carry out such an inspection system each candler should be instructed to place a tag bearing his initials or his number in each case or pail of eggs candled by him, so that when mistakes are found they can be traced and corrected. Each candler should direct his entire attention to his work and such distractions as conversation should not be permitted. A foreman versed in the handling of eggs and having executive ability is a prerequisite.

TABLE 10.—*Accuracy of individual inexperienced candlers at D house as determined by recandling rejects by candling-room foreman.*

Candler No.	Number of eggs examined.	Bad eggs.	Good eggs.	Kinds of good eggs.						
				Thick shells.	Heated.	Watery.	Good (carelessness).	Settled yolk.	Olive-green yolk.	Miscellaneous.
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1.....	144	94.4	5.6	4.2				0.7		0.7
2.....	111	92.0	8.0	3.9	0.6	0.6	1.7	.6	0.6	
3.....	132	87.0	13.0	7.40	1.9	.9		1.9	.9	
4.....	108	82.1	17.9	15.5	1.2			1.2		
5.....	84	80.9	18.9	6.3	5.4		2.7	4.5		
6.....	180	78.0	22.0	15.2	1.5	.8	1.5	1.5	1.5	

SUMMARY.

In bad eggs graded commercially by the candle as fit for food purposes there was found one group composed of eggs which could have been detected before the candle and another for which the present system is inadequate. The proportion of the first group in edible grades can, therefore, be taken as one measure of the efficiency of grading eggs by the candle.

The accuracy of candling depends upon the quality of the eggs and the skill of the candlers. With experienced workers the number of bad eggs found in high-grade eggs after candling is negligible. On

the other hand, when a large percentage of the good eggs in the supply have weak whites and yolks and the percentage of bad eggs runs high, the difficulty of distinguishing between edible and inedible eggs is increased, and the number of bad eggs miscandled is greater. In the studies with skilled candlers the average number of bad eggs miscandled in a case of 30 dozen varied from 0.20 in spring firsts to 10.77 in very low-grade refrigerator or cold-storage eggs. The number of bad eggs which could not be found by candling ranged from none to 6.93 per case, depending upon the grade of eggs examined. The data, as summarized from another point of view, show that out of 5,985 bad eggs present in 128,587 eggs, 71.65 per cent were detected by candling, 17.02 per cent were missed by candling, and 11.33 per cent were not distinguishable by candling.

Black rots, eggs with moldy spots, and eggs with heavily adherent yolks present such distinctive characteristics before the candle that their presence in edible grades is an evidence of carelessness. White rots, but more particularly mixed rots, eggs with yolks slightly stuck to the shell, blood rings, and eggs with bloody whites do not always show such striking features before the candle. These are the eggs which are found chiefly in the miscandled group of bad eggs. A brown shell or a light colored yolk is a factor which reduces the contrast between white and yolk, making differentiation between good and bad eggs more difficult.

Eggs with green whites and eggs with normal appearance but having bad odors constituted the group not recognizable by candling.

The good eggs which were frequently miscandled, especially by inexperienced candlers, were those with brown shells, hatch-spot eggs, weak eggs, eggs with the yolk floating near the shell, eggs with olive-colored yolks, and eggs with movable air cells. The average number of bad eggs found in the rejects by recandling was a dozen to the case, or less, with experienced candlers, and from 3 to 6 dozen with inexperienced candlers under good management. In the latter instance the candlers were directed to put all doubtful eggs with the rejects, which were then recandled by an expert. In plants having poor management and poor candlers the number of good eggs in the discards sometimes reached 11 dozen to the case.

The enforcement of a system of checking the work of individual candlers, particularly in plants employing inexperienced help, was found to be the best way to maintain high efficiency in a candling force.

TABLE 11.—Data in detail, showing accuracy of candling.

FRESH-MARKETED EGGS.

Grade.	Total number eggs examined.	Total bad eggs found.	Types of bad eggs detected by candling.												Types of bad eggs missed by candling.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																	
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			Total.	Black rots.	Heavily stuck yolks.	Moldy.	Large embryos.	White rots.	Slightly stuck yolks.	Blood rings.	Frozen yolks.	Mixed rots.	Bloody whites.	Crusted yolks.	Total.	Large embryos.	White rots.	Slightly stuck yolks.	Moldy.	Mixed rots.	Blood rings.	Bloody whites.	Crusted yolks.	Total.	Green whites.	Bad odors and normal appearance.																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																																						
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COLD-STORAGE EGGS.

<i>1914 firsts.</i>		5,023	131	90	13	2	35	9	2	2	9	20	18	5	7	6	23	12	11
April.....		5,366	211	157	29	16	66	13	2	2	15	16	34	3	11	12	20	16	4
May.....		3,508	42	35	4	1	3	8	4	4	1	1	2	1	...	1	5	2	3
June.....																			
<i>1915 firsts.</i>		5,362	355	200	8	...	75	23	25	25	47	22	106	2	36	8	49	34	15
June.....		4,198	392	232	22	...	46	37	23	23	82	22	118	2	48	13	42	33	9
July.....																			
<i>1914 dirty eggs.</i>		7,158	330	264	34	38	102	24	12	12	2	43	28	7	2	14	38	29	9
April.....		9,311	734	583	182	35	142	57	29	29	37	101	77	2	...	34	74	43	31
May.....		3,626	229	210	69	7	56	36	12	12	6	24	10	2	27	9	9	8	1
June.....		3,678	295	279	33	27	62	44	42	42	57	14	16	...	1	6	0	...	...
July.....																			
<i>1914 seconds.</i>		3,662	149	108	3	...	11	24	24	24	45	1	39	7	11	2	2	1	1
July.....																			
<i>1915 seconds.</i>		5,401	534	277	22	4	72	53	18	18	73	35	162	4	98	4	95	59	36
June.....		4,964	427	216	12	...	97	20	20	20	62	25	143	1	91	10	68	57	11
July.....																			
Total.....		61,257	3,829	2,651	431	130	767	328	213	213	3	324	753	27	312	1	425	294	131

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 703

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



WASHINGTON, D. C.



November 20, 1918

MISCELLANEOUS TRUCK-CROP INSECTS IN
LOUISIANA.

I.—INSECTS INJURIOUS TO THE GLOBE ARTICHOKE IN
LOUISIANA.

By THOS. H. JONES,

Entomological Assistant, Truck-Crop Insect Investigations.

INTRODUCTION.

Insect injury to the globe or burr artichoke (*Cynara scolymus*) apparently has received little attention from American economic entomologists. While the artichoke has not as yet attained the rank of an important food plant in the United States, the demand for the edible heads is increasing in the markets. The crop is grown in Louisiana, and since the fall of 1914, when the writer was assigned for work on truck-crop insects, in cooperation with the Louisiana Experiment Stations, many growers have complained of insect injury to the plants.

The most serious damage to the globe artichoke in Louisiana is caused by two species of plant-lice, or aphids, *Myzus braggii* Gillette and *Aphis rumicis* Linnaeus, both usually occurring in the same field and being most numerous during the late winter and in the spring.

INJURY CAUSED BY THE ARTICHOKE APHIS, MYZUS BRAGGII.

The artichoke aphis is the most common and, generally speaking, the most injurious insect enemy of the globe artichoke in Louisiana. It occurs in great abundance on the under sides of the leaves and its green color harmonizes with that of the leaf. In cases of severe infestation its presence brings about a condition such as that described in the following letter sent in by a correspondent in Rapides Parish: "Please let me know what to do for burr artichoke plants attacked by a dark smut which attracts large flies and bees. I had

the same disease attack my plants last year about the same time. Most of the plants recovered, but seem to have lost vitality and did not bear fruit as early or as plentifully as in former years." The presence of the "dark smut," the flies, and the bees referred to is accounted for by the "honeydew" from the aphids, and in fields where the Argentine ant (*Iridomyrmex humilis* Mayr) is present, this obnoxious pest attends the aphids. Besides this complaint from Rapides Parish, there are also at hand records of *Myzus braggii* injuring globe artichoke in East Baton Rouge, Ascension, Iberville, Terrebonne, and Plaquemines Parishes.¹

Myzus braggii also infests the yellow thistle (*Cirsium horridulum*) which is a common weed in Louisiana. (See Pl. I, fig. 1.) This plant is closely related, botanically, to the globe artichoke, so that the presence of the same species of insects on the two plants is to be expected. Prof. C. P. Gillette, who described *Myzus braggii*² from Colorado in 1908, and who has determined material sent to him from Louisiana, states that at Fort Collins, Colo., it is found on Canada thistle (*Cirsium arvense*) during the latter part of the summer and early fall, and that "the winter hosts are the Russian olive, *Hippophae rhamnoides*, and *Shepherdia arvensis*."³

ENEMIES OF THE ARTICHOKE APHIS.

While no internal parasite has been found attacking this aphis, a number of predacious insect enemies have been observed. These include the larvæ of the syrphid flies *Allograpta obliqua* Say and *Syrphus americanus* Weidemann, the larvæ and adults of the coccinellid or ladybird beetles *Scymnus puncticollis* LeConte, *Scymnus terminatus* Say, *Hippodamia convergens* Guérin, and *Cycloneda sanguinea* Linnaeus, as well as the larvæ of a chrysopid and a hemerobiid, both undetermined. The coccinellid beetle *Megilla maculata* DeGeer and the predacious bug *Triphleps insidiosus* Say have been taken on globe artichoke infested with *Myzus braggii* and probably feed upon this aphis. The aphid is attacked by a fungus, which Dr. A. T. Speare, Bureau of Entomology, has determined as *Entomophthora fresenii* Nowakowski. At Baton Rouge *Scymnus puncticollis* appears to be its most efficient enemy.

INJURY CAUSED BY THE BEAN APHIS, APHIS RUMICIS.

While not as common on globe artichoke in Louisiana as *Myzus braggii*, this aphis is more difficult to control by spraying than is the latter species, largely because of the fact that infested leaves

¹ Dr. F. H. Chittenden states that he has collected the species on globe artichoke at Washington, D. C.

² GILLETTE, C. P. NEW SPECIES OF COLORADO APHIDIDAE, WITH NOTES UPON THEIR LIFE HABITS. *In* Can. Ent., v. 40, no. 1, p. 17-20, pl. 1. 1908.

³ GILLETTE, C. P. CONFUSION OF RHOPALOSIPHUM HIPPOHAES KOCH, AND MYZUS BRAGGII GILLETTE. *In* Jour. Econ. Ent., v. 8, no. 3, p. 375-379, pl. 17, 18. 1915.

become distorted in such a manner that the aphids can be reached only with difficulty with a contact insecticide. (See Pl. II, figs. 1 and 2.)

CONTROL OF THE APHIDS ATTACKING ARTICHOKE.

During 1917 *Myzus braggii* and *Aphis rumicis* were controlled satisfactorily at Baton Rouge by spraying with 1 part, by weight, of nicotine solution (containing 40 per cent of nicotine as sulphate) to 1,000 parts of water, with laundry soap (standard, noncaustic type) added at the rate of 1 pound to 25 gallons of water. (See Pl. I, fig. 2, and Pl. III.) Because the plants in some rows in the field where the experiments were conducted were never sprayed, these plants served as a constant source of infestation for the sprayed plants, especially those near the untreated plants. The Argentine ant apparently was responsible in part for the spread of the aphids. More frequent sprayings were necessary, therefore, than would have been the case had all the plants in the field been sprayed. The plants were sprayed seven times, January 31, March 2, March 14, March 29, April 19, April 26, and May 26, respectively. The material was applied with a compressed-air sprayer holding about 3 gallons. The first picking of edible heads from the sprayed and unsprayed rows was made on May 11 and at frequent intervals thereafter until June 29. From 65 plants in the sprayed rows 310 heads or burrs were obtained and from 39 plants in the unsprayed rows 39 heads, an average of nearly 5 heads from each sprayed plant and an average of 1 from each unsprayed plant. The difference in growth made by the sprayed and unsprayed plants was very noticeable and if the weather had not been dry there is little doubt that the increase in the crop from the sprayed plants would have been still greater than that from the unsprayed plants.

It is especially advisable to begin spraying globe artichokes when the aphids first appear on the plants, which is usually when they are small. One reason for this is that after *Aphis rumicis* has become abundant the leaves are so badly distorted as a result of feeding that it is very difficult to reach them with the spray. Another reason for timely spraying is that if delayed until the aphids have reached their maximum abundance, much of the injury for which they are responsible already has been done, and as the period of maximum abundance under such conditions often comes when the plants have developed a heavy growth of leaves, a larger amount of spray material and more time for its application are required than when the spraying is done early. Some growers who spray for the control of the aphids, but who do not begin until the plants are large and heavily infested, find it advisable first to cut off and destroy the older and badly distorted leaves.

It is interesting to note that a company which grows each year from 10 to 15 acres of globe artichokes in Plaquemines Parish, Louisiana, has found that the aphids can be killed successfully by a nicotine-sulphate spray. Mr. E. P. Barrios, county agent of the parish, at whose suggestion the spraying was begun, has furnished the writer with the following information regarding the methods followed. The spray mixture, which is applied with knapsack sprayers equipped with angled nozzles, is made up as follows:

Tobacco extract containing 40 per cent nicotine as sulphate	ounces__	8
Fish-oil soap	-----pounds__	3
Water	-----gallons__	50

This mixture contains 1 part of nicotine sulphate to 800 parts of water. As an additional aid in controlling the aphids, the method of planting followed makes it possible to utilize the same ground for artichokes during successive years. The young shoots are transplanted each fall in rows between the rows of old plants. Since the old rows are placed 8 feet apart there is ample space between rows to make this practical. When the young sets have taken root the old plants are plowed under and, as they are well covered with dirt, the aphids present on them are killed. The aphids on the young plants now may be more readily controlled by spraying, because of the smaller amount of foliage they present.

It is possible that aphids on globe artichokes could be economically killed by fumigation, especially when only a few are grown, and for this purpose nicotine paper might be utilized, a cover to confine the fumes being placed over each plant as it is fumigated.

OTHER INSECTS ATTACKING THE GLOBE ARTICHOKE IN LOUISIANA.

The banded leaf-footed plant-bug, *Leptoglossus phyllopus* Linnaeus, feeds on the globe artichoke. Its normal food plant, as has been noted by Chittenden,¹ is the yellow thistle, *Carduus spinosissimus* (= *Cirsium horridulum*). The adults and nymphs are often numerous upon both plants, the adults being especially common on the thistle during late winter and early spring.

Larvæ of the corn earworm (*Chloridea obsoleta* Fabricius) have been found boring into the edible heads, and a plant-bug, *Thyreocoris pulicarius* Germar, has been observed clustered upon them. Nymphs of *Nezara viridula* Linnaeus have been found on the heads, and a scarabæid beetle, *Euphoria sepulchralis* Fabricius, has been captured under conditions indicating that it was injuring them.

¹ CHITTENDEN, F. H. SOME INSECTS INJURIOUS TO GARDEN AND ORCHARD CROPS. U. S. Dept. Agr. Bur. Ent. Bul. 19, n. s., 1899. See p. 47.

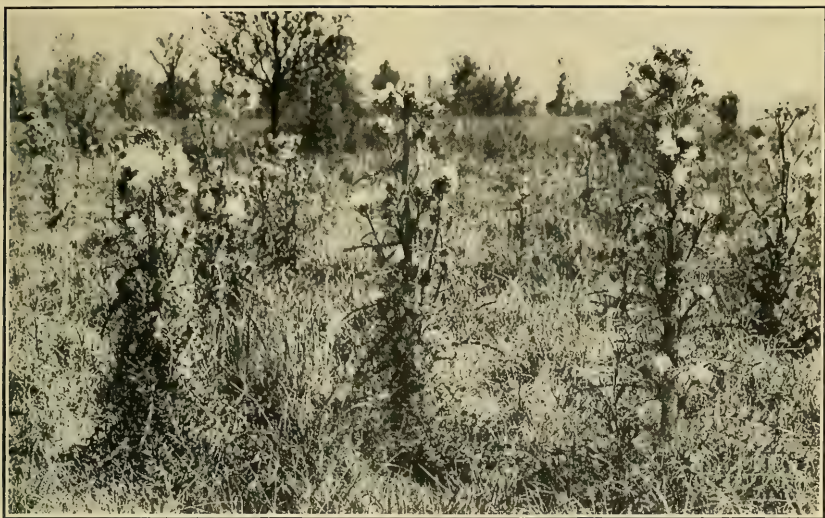


FIG. 1.—YELLOW THISTLE (*CIRSIMUM HORRIDULUM*), A COMMON WEED IN UNCULTIVATED FIELDS IN LOUISIANA.

It is closely related to the globe artichoke, and some of the aphids which attack the latter feed on the thistle.



FIG. 2.—GLOBE ARTICHOKES ON WHICH APHIDS, *MYZUS BRAGGII*, HAVE BEEN CONTROLLED BY SPRAYING.

WILD AND CULTIVATED FOOD PLANTS OF *MYZUS BRAGGII*.



FIG. 1.—YOUNG PLANT INJURED BY THE BEAN APHIS (*APHIS RUMICIS*).



FIG. 2.—HEALTHY YOUNG PLANT, SHOWING BENEFITS OF SPRAYING.

THE GLOBE ARTICHOKE AND APHIDS.



SPRAYED AND UNSPRAYED ROWS OF GLOBE ARTICHOKE.

The aphids *Myzus braggii* and *Aphis rumicis* have been controlled in the row at left by spraying with nicotine sulphate. The plants in the row at right have not been sprayed.

Cutworms, the predominating species apparently being *Feltia annexa* Treitschke and *Agrotis ypsilon* Rottensburg, cause some injury, especially during the cooler months of the year when only the smaller developing leaves are present on the plants.

Larvæ of two agromyzid flies, *Agromyza platyptera* Thomson var. *jucunda* Van der Wulp, and *Agromyza* sp.,¹ have been found mining in the leaves and the membracid *Entylia sinuata* Fabricius breeds on them. The leaves are also fed upon to some extent by various other insects, among them the larva of the cabbage looper (*Autographa brassicae* Riley) and the adult of the southern corn rootworm (*Diabrotica duodecimpunctata* Olivier).

¹ Determined by F. R. Cole. In 1914 Mr. I. J. Condit found larvæ of *Phytomyza* (*Napomyza*) *lateralis* Fallén working as leaf miners on globe artichokes at Berkeley, Cal. The reared adults were determined by Mr. Frederick Knab, Bureau of Entomology.



II.—THE GRANULATED CUTWORM,¹ AN IMPORTANT ENEMY OF VEGETABLE CROPS IN LOUISIANA.

By THOS. H. JONES,

Entomological Assistant, Truck-Crop Insect Investigations.

INTRODUCTION.

Cutworms periodically cause serious damage to vegetable crops in Louisiana and adjacent territory and it is seldom that they do not occur, at least in small numbers, in land planted to such crops. Complaints of injury are often made by people who have small gardens as well as by those who make the growing of truck crops their livelihood.

Observations made in the State from 1914 to 1917, inclusive, indicate that the granulated cutworm (*Feltia annexa* Treitschke) (fig. 1) is the principal species attacking vegetables.²

Of 1,431 cutworms, representing collections made from about injured plants at Baton Rouge during the months of April, June, July, August, October, November, and December, of 1915, 1916, and 1917, 1,345, practically 94 per cent, were identified as *Feltia annexa*. The proportion of this species, in one collection, was as low as 76 per cent, but at other times it exceeded 90 per cent. The remainder of the collections noted was composed of 47 larvæ of *Agrotis ypsilon* Rottemburg (3.2 per cent), 35 larvæ of *Feltia malefida* Guenée (2.5 per cent), and 4 larvæ of undetermined species.

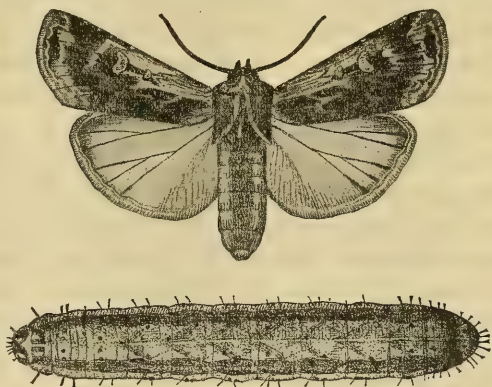


FIG. 1.—The granulated cutworm: Moth above, larva below. Somewhat enlarged. (Chittenden.)

¹ *Feltia annexa* Treitschke.

² Messrs. C. E. Smith, J. L. E. Lauderdale, and M. R. Smith, who were stationed at Baton Rouge, La., for the Bureau of Entomology during this period, rendered valuable assistance in the investigations upon which this paper is based.

NATURE OF DAMAGE.

As is true with other cutworms, the most serious damage done by the granulated cutworm is due to its habit of cutting off small plants near the surface of the ground. Two other types of injury have been noted. Where the plant is too large to be severed near the surface the larva ascends the plant and feeds on the foliage. (See Pl. IV, A, B.) Since feeding is done at night the cause of the damage often is not known to the grower. Irish potatoes, beets, and Brussels sprouts have been observed that were defoliated in this way, examination revealing numerous larvæ secreted in the soil beneath.

The other type of injury is to the fruit of certain plants, principally when it rests on the ground. The fruit of tomato and eggplant, if so located, is sometimes bored into and made unsalable. (Pl. IV, C.)

DESCRIPTION OF STAGES.

THE MOTH.

The moth (fig. 1) is one of the somber-colored species of the family Noctuidæ. The fore-wings are covered above with brown, gray, and black scales, among which a few white ones are often present. These scales are so arranged that portions of the wings are brown or gray, or a mixture of the two colors, with black markings. The fore-wings of certain individuals may in general be darker or lighter than those of others of the same sex, but those of the female usually are darker than those of the male. The hind wings are white, more or less dusky along the margins and veins. The antennæ of the male are pectinate, those of the female not pectinate. Ten mounted males averaged 37 mm. in width from tip to tip of the fore-wings, the width ranging from 31 to 40 mm. Ten females averaged 40.4 mm., the widths ranging from 37 to 43 mm. The following is the description by Hampson:¹

♂ [Male]. Head and thorax red-brown slightly mixed with fuscous; tegulae with slight black medial line; legs black and brown; abdomen pale red-brown, the ventral surface whitish. Fore wing pale red-brown, with some fuscous suffusion below base of cell and on costal area before apex; an indistinct double, waved, black subbasal line from costa to vein 1; the antemedial line double, very strongly dentate outwards below costa, in cell and above inner margin, and angled outwards in submedian fold; the claviform defined by black, narrow and elongate; the orbicular and reniform small, defined by black, the former oblique elliptical, open above, and with a black streak in the cell between it and the reniform; the postmedial line indistinct, strongly dentate, bent outwards below costa, and oblique below vein 4; the subterminal line represented by a series of pale and fuscous dentate marks; the veins of terminal area streaked with black, and with a terminal series of black points. Hind wing semihyaline white, the costa and cilia at apex slightly tinged with brown.

♀ [Female]. Fore wing suffused with fuscous, leaving the costal area to end of cell and the terminal area brown.

¹ HAMPSON, GEORGE F. CATALOGUE OF THE NOCTUIDÆ IN THE COLLECTION OF THE BRITISH MUSEUM. In *Catalogue of the Lepidoptera Phalaenae in the British Museum*, v. 4, p. 354-355. London, 1903.

THE EGG.

The egg approaches a hemisphere in shape, the smooth lower surface being at most only slightly convex. About 38 small ridges or ribs originate at the base and converge toward the apex, to which not all of them persist. Crossing between these ribs are numerous smaller ones. A minute "button" is present at the apex. The egg when first laid is yellowish white, becoming darker before hatching. The diameters of 15 eggs gave an average of 0.64 mm., ranging from 0.60 to 0.69 mm.

THE LARVA.

The following description of the larva, by Dr. H. G. Dyar, is taken from Hampson:¹

Head 3.5 millim., pale brown, pale reticulate, vertical band dark brown, strongly angled at top of clypeus, which is brown filled. Cervical shield well cornified, shining brown, cut by a pale dorsal line and traces of a subdorsal one. Dorsal space broadly pale, faintly brown, clouded on the centres of the segments, heaviest next the obscure, pale, dorsal line. Skin rather thin, smooth. Lateral space brown with faint pale subdorsal and lateral lines. Substigmatal band broad, distinctly but not brightly or very uniformly white-pigmented, the subvertical area becoming translucent. Tubercles dark brown, rather large and distinctly cornified; anal plate brown.

THE PUPA.

Riley has already given a very good description of the pupa and the following is taken in part from his notes:²

General color brown ochre, the surface smooth and glistening, except for impressions. In specimens from which the adult is about to issue the color becomes of a darker brown, the eyes black. Head small, with front slightly prolonged. Posterior lateral angle of prothorax with a dark brown transverse swelling, which closes the first spiracle. Abdomen with dorsal surface of segments 4-7 anteriorly with a transverse, rounded, darker brown ridge, marked with quite a number of very coarse and deep impressions. On segments 5-7 these ridges encircle the segments, though on the ventral surface they are not dark brown and the impressions are not as prominent. Stigmata black. Tip of last segment dark brown, ending in two stout teeth, each terminating in a very fine spine, which is curved downward. Each side, just before the tip, is a small blackish tubercle, and, dorsally, a little in front of this is a short spine.

Ten pupæ averaged 18.6 mm. in length and 5.9 mm. in lateral width across the third abdominal segment, ranging in length from 17 to 20.5 mm., and in width from 5 to 6 mm.

FOOD PLANTS.

The larvæ are very general feeders and probably attack practically all vegetable crops. We have found them injuring bean, beet,

¹ Op. cit., p. 355.

² RILEY, C. V. THE GRANULATED CUTWORM (LARVA OF *AGROTIS ANNEXA* TREITSCHKE). In Report of the Entomologist, Ann. Rpt. U. S. Commr. Agr. f. 1884, p. 291, 292, Pl. II, fig. 1. 1885.

Brussels sprouts, cabbage, cauliflower, eggplant, Irish potato, pepper, tomato, and turnip.

LIFE HISTORY AND HABITS.

HABITS OF THE MOTH.

In the insectary the moths remain inactive during the day. In the field their activities probably take place at night, the moths secreting themselves during the day in places that are at most only poorly lighted. Specimens either have been collected in the field or have issued in a well-ventilated insectary during all months of the year except April and June.

OVIPOSITION.

No eggs have been collected in the field. In the insectary they were deposited at night singly over objects to which the moths had access, with the flattened side of the egg adhering to the surface upon which it rested. Riley has stated that moths which he had under observation scattered their eggs irregularly and singly on grass, though he considered this habit exceptional and probably abnormal, as a result of confinement.

NUMBER OF EGGS DEPOSITED.

During 1917 females were confined in the insectary and records kept of the number of eggs deposited by each. They were fed sweetened water and, once egg-laying had begun, eggs usually were deposited every night during the period of oviposition. The number of eggs deposited by different moths, the number of well-developed eggs in the ovaries at death, and the number of eggs deposited daily by a single moth, varied greatly. The highest number deposited during a single night was 307. During December eggs were deposited on a night when the thermograph registered as low as 19° F. The confinement of males with females apparently had no bearing on the number of eggs deposited. Males kept alone and with females lived as long as did the females. Table I gives data concerning the female moths.

TABLE I.—Egg-laying records of *Feltia annexa*, Baton Rouge, La., 1917.

Female moth issued.	First eggs laid.	Last eggs laid.	Moth died.	Total number eggs laid.	Number of eggs in ovaries at death.	Total number of eggs.
1917	1917	1917	1917			
Sept. 10.....	Sept. 12	Sept. 20	Sept. 20	812	0	812
Nov. 19 ¹	Nov. 22	Dec. 9	Dec. 11	878	385	1,263
Nov. 22.....	Nov. 29	Dec. 6	Dec. 14	47	392	439
Nov. 17.....	Nov. 20	Dec. 8	Dec. 15	1,106	268	1,374
Nov. 11.....	Nov. 18	Dec. 8	Dec. 17	361	420	781
Dec. 4.....			Dec. 18	0	311	311
Nov. 30.....	Dec. 2	Dec. 8	Dec. 19	5	433	438
Dec. 2.....	Dec. 4	Dec. 26	Dec. 27	883	0	883
Nov. 29 ¹	Dec. 3	Dec. 26	Dec. 30	1,060	79	1,139
Nov. 7.....	Dec. 22	Dec. 29	Dec. 30	142	360	502

¹ Confined with male.

HABITS OF THE LARVA.

The larvæ feed at night, and during the day usually are found in the soil near the plants upon which they have fed the previous night. At Baton Rouge larvæ have been taken in the field during all months except March, May, and September, and it is believed that they may be found throughout the year. There are apparently five and possibly six generations a year in this locality, and these so overlap that, at certain times, all stages are present in the field simultaneously.

There has been considerable variation in the number of times larvæ have molted in confinement. Some were observed to have 5, some 6, and others 7 larval instars. Larvæ from the same lot of eggs varied in this respect, though usually there was a variation of only one instar. Generally the individuals that spent the longest time in the larva stage underwent the least number of molts.

LENGTH OF EGG, LARVA, AND PUPA STAGES.

The length of time spent in the egg, larva, and pupa stages is governed apparently by the temperatures to which these stages are exposed. Table II, collated from notes, gives data on eggs, larvæ, and pupæ under observation at different seasons of the year in the insectary at Baton Rouge. The minimum period for the egg, larva, and pupa stages combined was as low as 38 days during July and August, while a period of 54 days was spent in the egg stage alone during December, 1917, and January, 1918. At this time temperatures below 30° F. were several times recorded on a near-by thermometer and during this period 8° F. and 11° F. were registered. These low temperatures prevailed during a period of weather unusually cool for Baton Rouge and were apparently the cause of the failure of many of the eggs to hatch. Some larvæ that issued on January 6 also were killed, apparently by these temperatures, although others survived.

TABLE II.—Lengths of egg, larva, and pupa stages of *Feltia annexa*, Baton Rouge, La., 1917.

Eggs deposited.	Eggs hatched.	Number days in egg stage.	Larvæ issued.	Larvæ pupated.	Number larvæ under observation.
July 14, 1917	July 18, 1917	4	July 18, 1917.....	Aug. 10-14, 1917 ¹	12
Aug. 25, 1916	Aug. 31, 1916	6	Aug. 31, 1916.....	Sept. 24-Oct. 6, 1916.....	19
Oct. 22, 1916	Nov. 3, 1916	12	Nov. 10, 1915.....	Jan. 13-29, 1916.....	11
Dec. 6, 1917	Jan. 29, 1918	54	Mar. 13, 1917.....	Apr. 25-30, 1917.....	19
Number days in larva stage.	Larvæ pupated.		Adults emerged.		Number pupæ under observation.
23-27	Aug. 10-14, 1917.....		Aug. 21-26, 1917.....		12
24-36	Sept. 24-Oct. 6, 1916.....		Oct. 12-26, 1916.....		19
64-80	Jan. 13-29, 1916.....		Mar. 6-20, 1916.....		11
43-48	Apr. 25-30, 1917.....		May 12-20, 1917.....		19
					11-14
					18-20
					45-53
					19-21

¹ Larvæ stopped feeding and entered soil Aug. 8-12 and it is assumed that they pupated two days later.

ENEMIES.

A tachina fly, *Linnaemyia comta* Fall., identified by W. R. Walton, and an ichneumon fly, *Enicospilus purgatus* Say, identified by A. B. Gahan, have been reared from larvæ collected at Baton Rouge. A sarcophagid fly, determined by J. M. Aldrich as *Sarcophaga heli-cis* Townsend, issued from a rearing jar containing larvæ of *Feltia annexa* and may have been parasitic on them. Dead larvæ, invested with fungus, have been found also in rearing cages. The fungus has been identified by Dr. A. T. Speare as *Entomophthora virescens* Thaxter.

METHODS OF CONTROL.

Experiments indicate that, of the four methods of control following, only the use of poisoned baits and the treatment of attacked plants with arsenicals will prove satisfactory. The latter method is especially applicable when large plants are being injured and in certain instances, especially where severe injury to foliage is being done, both methods might be used simultaneously to advantage.

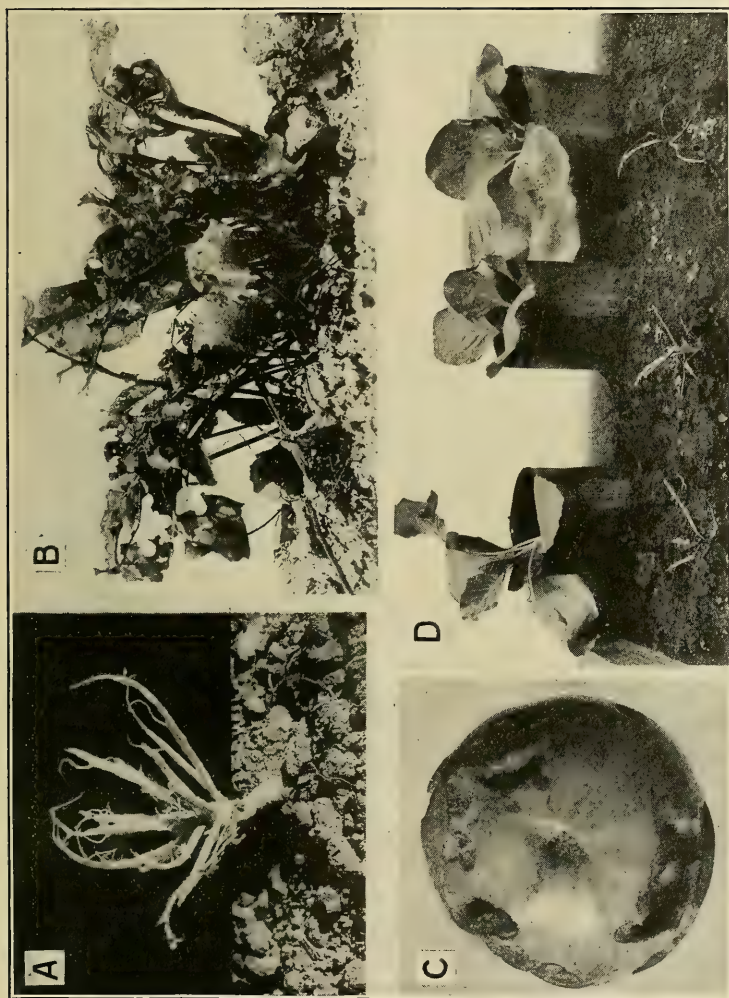
HAND PICKING.

One control measure is suggested by the fact that larvæ are found during the day in soil about plants on which they have fed during the previous night. This method is sometimes followed in Louisiana. Vegetable fields, usually fields where transplanting has been recently done, are examined and when cutworm injury is noted, search for the larva is made in the soil about the base of the damaged plant. If the larva is discovered it is killed. This work can be done best in the early morning. Later in the day wilting of the severed part of the plant makes it more difficult to locate the injury, and the larva may move from the injured plant or bury itself deeper in the soil as the day advances.

This method of control, even if practiced for several days and carefully done, is expensive and by no means satisfactory. It is impossible to discover all the larvæ in a field by following such a method and the plan furthermore rests on the unsatisfactory basis that some injury must be done before the larva is killed. If larvæ are abundant, a large number of young plants are often cut off during the first night after they have been set out.

BARRIERS AROUND PLANTS.

Experiments made in cages and in the field indicate that in setting out plants injury may be reduced, to a certain degree, by wrapping the stems with newspaper or oiled paper, or placing cylinders of wrapping paper or metal about them. Such practices do not entirely



THE GRANULATED CUTWORM.

A.—Plant of Brussels sprouts injured by larvæ in the field. B.—Injury to beet foliage by larvæ in the field. C.—Tomato fruit injured by larvæ. D.—Cabbage plants showing value of tin cans in preventing injury by larvæ.



THE GRANULATED CUTWORM.

Showing value of spraying in controlling the larvæ. The same number of cabbage plants were in each box at the time equal numbers of larvæ were confined in each. The photographs were taken 23 days later. A.—Sprayed plants. B.—Unsprayed plants.

prevent injury and besides the expense of placing these barriers around the plants, their presence may retard the growth of the plants. In the experiments larvæ sometimes ascended the barriers, either when the stems were wrapped with the material or when the barrier was at some little distance from the stem. If food plants, unprotected by barriers, are present there is less damage to the protected plants than is the case when only protected plants can be reached. This is shown in Plate IV, A, B, D. The plants protected by the cans, containers such as canned goods are sold in, with the tops and bottoms removed, show no injury, while the unprotected plants have been seriously fed upon.

POISONED BAITS.

Satisfactory results have been obtained in destroying the larvæ in cages and in the field with poisoned bran mash. A mixture made up in the following proportions has given good results:

Bran	pounds--	10
Molasses	quart--	1
Paris green	pound--	$\frac{1}{2}$
Water	quarts--	7
Juice and finely chopped rind and pulp of 2 oranges.		

In cages where young cabbage plants were growing larvæ were observed to feed upon this poisoned mash after it had been scattered thinly over the soil. No damage to the plants was noted and larvæ were dead on the following day. Of 202 larvæ collected from the soil 88 per cent were dead within three days after the mixture had been scattered over a field of Brussels sprouts that were being injured. A portion of the remainder apparently were not killed because they had completed their growth and stopped feeding before the poisoned mash was put out.

A mixture of 20 pounds of bran, 2 pounds of powdered arsenate of lead, $\frac{1}{2}$ gallon of molasses, and about 14 quarts of water has also given good results in killing larvæ in the field.

When the larvæ are found to occur in abundance in a field at plowing time and this field is to be immediately planted, it would seem advisable to apply poisoned baits before the field is planted rather than to wait until the crop shows injury.

TREATING PLANTS WITH ARSENICALS.

When the larvæ are feeding upon the leaves of plants it is possible to reduce their numbers by applying arsenicals to the foliage. This method is especially applicable in the case of plants that have reached a considerable size, and under certain conditions the arsenical may at the same time prevent injury by other leaf-eating insects. Plate V shows two boxes of cabbage plants. The plants in

one box were sprayed with powdered arsenate of lead at the rate of 2 pounds to 50 gallons of water, with 2 pounds of yellow laundry soap added. The plants in the other box were left untreated. Larvæ were then confined in both boxes. The appearance of the sprayed plants 23 days later is shown in Plate V, A, and that of the unsprayed plants in Plate V, B. The larvæ in the box containing the foliage to which poison was applied fed but little before being killed, while those in the other box continued to feed until their larval growth was completed.

III.—EXPERIMENTS IN CONTROLLING THE TOMATO FRUITWORM WITH ARSENICALS.

By THOS. H. JONES,

Entomological Assistant, Truck-Crop Insect Investigations.

Spraying and dusting experiments for the control of the tomato fruitworm (*Chloridea obsoleta* Fabricius) were conducted during 1916 and 1917 at the Louisiana Experiment Station, Baton Rouge, La. This work was carried on in cooperation with Dr. C. W. Edger-ton, plant pathologist of the station, who was especially interested in the fungicidal value of some of the materials used.

In 1916 a spring and a fall crop of tomatoes were used in the experiments. In the case of the fall crop a heavy frost occurred before much fruit had matured. The next day all fruit was gathered and weighings and counts made. In 1917 only a spring crop was used in the experiments.

The sprays were applied by means of small compressed-air sprayers of about $2\frac{1}{2}$ gallons capacity. The materials were carefully applied. On the spring crop of 1916 about 10 gallons of spray were used on an average in spraying eight times a row of 54 plants, set 2 feet apart in the row. On the fall crop of 1916 approximately $4\frac{3}{4}$ gallons were used in spraying the same number of plants seven times. For spraying the same number of plants five times in the spring of 1917 about 7 gallons were used.

The dusting was done with a dust gun. In dusting the spring crop of 1916 approximately 17 ounces of undiluted powdered arsenate of lead were used in making eight applications to an average row of 54 plants, set 2 feet apart in the rows. In dusting the same number of plants of the spring crop of 1917 five times, approximately $12\frac{1}{2}$ ounces were used. For the dusting a specially prepared, light, finely powdered arsenate of lead was used, as was also used in spraying the spring crop of 1916.

In Tables I-III "wormy" refers to fruit that was apparently injured by the larva of *Chloridea obsoleta*. Without doubt the injury to a small percentage of this fruit was due to other causes, principally the hornworms, *Phlegethontius* spp. and larvæ of the granulated cutworm *Feltia annexa* Treitschke.

TABLE I.—*Tomatoes set out in field Apr. 11, 1916. Applications of sprays and dusts made Apr. 25, May 5, May 15, May 24, June 2, June 12, June 22, July 3, and July 13. No. 3 not sprayed after May 24. No. 4 not sprayed after June 12. Nos. 5, 6, and 7 not sprayed, and No. 9 not dusted, after July 3. Harvesting began June 14, ended Aug. 3.*

EARLIANA VARIETY.

No.	Material used.	Number of applications.	Total weight tomatoes.	Weight wormy.	Per cent weight wormy.	Total number tomatoes.	Number wormy.	Per cent wormy.
			<i>Pounds.</i>	<i>Pounds.</i>				
1	Check.....	-----	266.7	73.1	27.4	1,413	436	30.8
2	Bordeaux mixture, 4-4-50.....	9	297.5	61.0	20.5	1,718	357	20.7
3	Commercial powdered arsenate of lead, 1½ pounds to 50 gallons 4-4-50 Bordeaux mixture.....	4	216.9	49.8	22.9	1,441	368	25.5
4	Same as No. 3.....	6	359.4	63.4	17.6	1,862	344	17.9
5	do.....	8	262.5	29.2	11.1	1,415	177	12.5
6	Commercial Bordeaux and arsenate of lead mixture, 1 pound to 6 gallons water.....	8	229.1	24.8	10.8	1,392	157	11.2
7	Commercial powdered arsenate of lead, 1½ pounds to 50 gallons water.....	8	238.2	23.2	9.7	1,385	145	10.4
8	Dusted with 9 parts powdered sulphur and 1 part commercial powdered arsenate of lead, by weight.....	9	303.1	30.2	9.9	1,786	170	9.5
9	Dusted with commercial powdered arsenate of lead, undiluted.....	8	348.4	21.1	6.0	1,468	105	7.1

GLOBE VARIETY.

1	Check.....	-----	203.8	36.8	18.1	1,180	211	17.8
2	Bordeaux mixture, 4-4-50.....	9	236.8	23.8	10.0	1,252	126	10.0
3	Commercial powdered arsenate of lead, 1½ pounds to 50 gallons 4-4-50 Bordeaux mixture.....	4	190.6	13.0	6.8	1,120	86	7.7
5	Same as No. 3.....	8	221.4	11.6	5.2	1,073	51	4.7
6	Commercial Bordeaux and arsenate of lead mixture, 1 pound to 6 gallons water.....	8	317.5	19.2	6.0	1,468	92	6.2
7	Commercial powdered arsenate of lead, 1½ pounds to 50 gallons water.....	8	254.2	16.8	6.6	1,318	74	5.6
8	Dusted with 9 parts powdered sulphur and 1 part commercial powdered arsenate of lead, by weight.....	9	275.2	16.8	6.1	1,331	75	5.6
9	Dusted with commercial powdered arsenate of lead, undiluted.....	8	249.6	10.9	4.3	1,474	46	3.1

TABLE II.—*Tomatoes set out in field Aug. 14 and 15, 1916. Applications of sprays made Sept. 2, Sept. 12, Sept. 22, Oct. 2, Oct. 12, Oct. 23, and Nov. 2. Harvesting began Oct. 24, ended Nov. 15.*

EARLIANA VARIETY.

No.	Material used.	Number of applications.	Total weight tomatoes.	Weight wormy.	Per cent weight wormy.	Total number tomatoes.	Number wormy.	Per cent wormy.
			<i>Pounds.</i>	<i>Pounds.</i>				
1	Check.....	-----	41.2	9.3	22.5	588	113	19.2
2	Bordeaux mixture, 4-4-50.....	7	100.1	27.8	27.7	849	241	28.3
3	Commercial powdered arsenate of lead, 3 pounds to 50 gallons 4-4-50 Bordeaux mixture.....	7	109.5	16.9	15.4	1,012	144	14.2
4	Commercial powdered arsenite of zinc, 3 pounds to 50 gallons water.....	7	113.9	19.3	16.9	1,122	188	16.7
5	Commercial Bordeaux and arsenate of lead mixture, 1 pound to 6 gallons water.....	7	108.7	15.5	14.2	1,147	139	12.1
6	Commercial powdered arsenate of lead, 3 poundsto 50 gallons water.....	7	80.5	11.3	14.0	880	112	12.7

TABLE II.—*Tomatoes set out in field Aug. 14 and 15, 1916—Continued.*HYBRID VARIETY.¹

No.	Material used.	Number of applications.	Total weight tomatoes.	Weight wormy.	Per cent weight wormy.	Total number tomatoes.	Number wormy.	Per cent wormy.
1	Check.....	-----	69.2	9.3	13.4	694	93	13.4
2	Bordeaux mixture, 4-4-50.....	7	66.9	13.3	19.8	546	94	17.2
3	Commercial powdered arsenate of lead, 3 pounds to 50 gallons 4-4-50 Bordeaux mixture.....	7	82.3	11.1	13.4	724	73	10.0
4	Commercial powdered arsenite of zinc, 3 pounds to 50 gallons water.....	7	107.3	12.7	11.8	852	88	10.3
5	Commercial Bordeaux and arsenate of lead mixture, 1 pound to 6 gallons water.....	7	95.9	11.3	11.7	856	78	9.1
6	Commercial powdered arsenate of lead, 3 pounds to 50 gallons water.....	7	57.7	3.8	6.5	597	33	5.5

¹ Hybrid selected by Dr. Edgerton, the parents being the Earliana and a wilt-resistant hybrid.TABLE III.—*Tomatoes set out in field Apr. 4 and 6, 1917. Applications of sprays and dust made May 3, May 12, May 22, June 1, and June 12. Harvesting began June 11, ended Aug. 11.*

EARLIANA VARIETY.

No.	Material used.	Number of applications.	Total weight tomatoes.	Weight wormy.	Per cent weight wormy.	Total number tomatoes.	Number wormy.	Per cent wormy.
			<i>Pounds.</i>	<i>Pounds.</i>				
1	Check.....	-----	247.1	47.9	19.3	1,747	398	22.7
2	Bordeaux mixture, 4-4-50.....	5	216.7	41.5	19.1	1,682	370	21.9
3	Commercial powdered arsenate of lead, 3 pounds to 50 gallons water.....	5	303.1	37.4	12.3	2,102	362	17.2
4	Commercial Bordeaux and arsenate of lead mixture, 1 pound to 6 gallons water.....	5	261.8	31.8	12.1	1,850	317	17.1
5	Commercial powdered arsenate of lead, 3 pounds to 50 gallons 4-4-50 Bordeaux mixture.....	5	297.0	38.8	13.0	1,929	313	16.2
6	Commercial powdered arsenite of zinc, 3 pounds to 50 gallons water.....	5	265.5	27.8	10.4	1,856	270	14.5
7	Commercial powdered arsenate of calcium, 3 pounds to 50 gallons water.....	5	298.2	31.8	10.6	1,936	270	13.9

GLOBE VARIETY.

No.	Material used.	Number of applications.	Total weight tomatoes.	Weight wormy.	Per cent weight wormy.	Total number tomatoes.	Number wormy.	Per cent wormy.
1	Check.....	-----	211.7	24.2	11.4	1,473	207	14.0
2	Commercial powdered arsenate of calcium, 3 pounds to 50 gallons water.....	5	248.5	28.0	11.2	1,695	247	14.5
3	Bordeaux mixture, 4-4-50.....	5	194.8	22.5	11.5	1,240	175	14.1
4	Commercial powdered arsenite of zinc, 3 pounds to 50 gallons water.....	5	227.5	22.1	9.7	1,597	200	12.5
5	Commercial powdered arsenate of lead, 3 pounds to 50 gallons 4-4-50 Bordeaux mixture.....	5	186.6	21.0	11.2	1,219	150	12.3
6	Commercial powdered arsenate of lead, 3 pounds to 50 gallons water.....	5	247.4	20.7	8.3	1,701	180	10.5
7	Commercial Bordeaux and arsenate of lead mixture, 1 pound to 6 gallons water.....	5	205.1	19.5	9.5	1,570	159	10.1

THIRTEEN VARIETIES.

No.	Material used.	Number of applications.	Total weight tomatoes.	Weight wormy.	Per cent weight wormy.	Total number tomatoes.	Number wormy.	Per cent wormy.
1	Check.....	-----	228.0	43.2	18.9	1,438	335	23.2
2	Dusted with commercial powdered arsenate of lead, undiluted.....	5	159.3	11.9	7.4	1,199	124	10.3

The results of the two years' work show considerable variation. None of the treatments can be considered to have reduced the injury profitably. Arsenate of lead, applied undiluted as a dust, gave the

best results. It was to be expected that the sprays and dusts used on the spring crop of 1916 would show better results than those used on the spring crop of 1917, as in 1916 their application was continued longer after harvesting began. On the fall crop of 1916, however, where harvesting was completed 13 days after the last spraying, the spraying apparently had little or no effect in some instances in reducing injury. In this connection it should be stated, however, that the plants used as checks produced but a small amount of fruit, partly because they were badly injured by *Phlegethontius* larvæ when small. Comparisons of results from sprayed and check plants may, therefore, not be indicative of the true value of the sprays.

It is to be noted that the Earliana variety of tomato showed a higher percentage of injured fruit than did either the Globe or the hybrid.

The diagrams (figs. 2-5) show the number of tomatoes produced each week by Earliana and Globe plants set out in the springs of 1916 and 1917, part of these being sprayed with arsenate of lead and the others serving as a check. The percentage of the number of fruit showing injury is also given. The diagrams show that the Earliana produced the greater portion of its crop sooner than did the Globe and that in 1916 both varieties produced their crops within a shorter period of time than in 1917, there being a pronounced "second crop" during 1917.

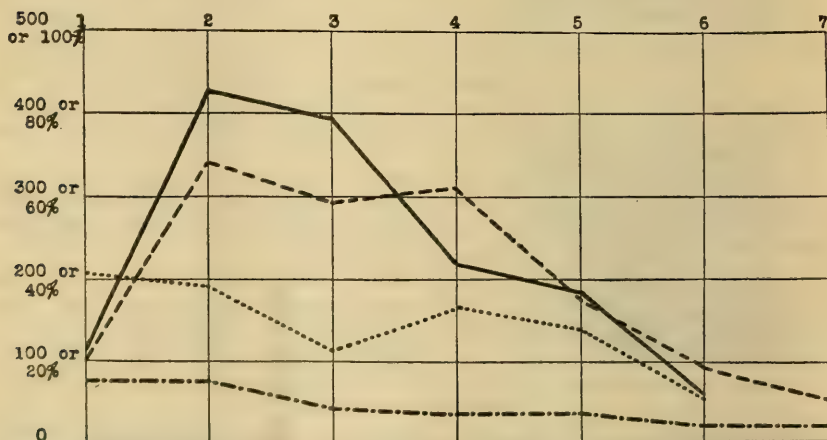


FIG. 2.—Diagram, prepared from weekly totals during harvesting season, showing number of tomatoes of the Earliana variety and percentage apparently injured by the tomato fruitworm in 1916. Spaces between horizontal lines represent 100 in case of total number of tomatoes, and 20 in case of percentage wormy. Vertical lines represent weeks. The solid line represents the total number of tomatoes from the unsprayed check; the dotted line, the percentage of check wormy; the line of dashes, the total number of tomatoes from plants sprayed with arsenate of lead; the line of dots and dashes, the percentage of sprayed tomatoes wormy.

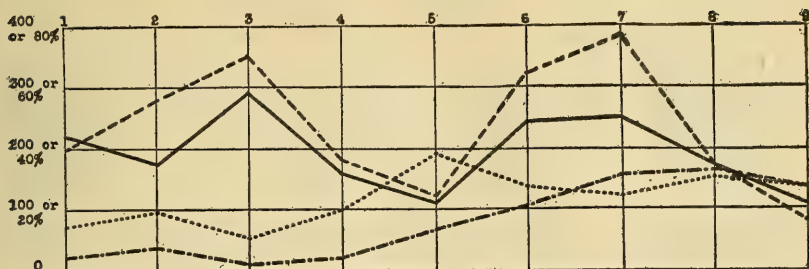


FIG. 3.—Diagram, prepared from weekly totals during harvesting season, showing number of tomatoes of the Earliana variety and percentage apparently injured by the tomato fruitworm in 1917. Spaces between horizontal lines represent 100 in case of total number of tomatoes, and 20 in case of percentage wormy. Vertical lines represent weeks. The solid line represents the total number of tomatoes from the unsprayed check; the dotted line, the percentage of check wormy; the line of dashes, the total number of tomatoes from plants sprayed with arsenate of lead; the line of dots and dashes, the percentage of sprayed tomatoes wormy.

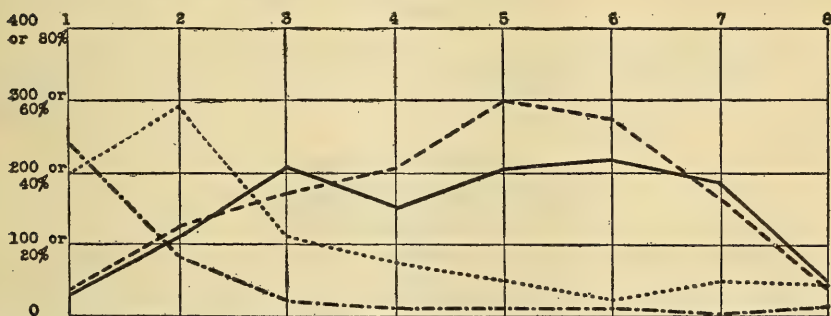


FIG. 4.—Diagram, prepared from weekly totals during harvesting season, showing number of tomatoes of the Globe variety and percentage apparently injured by the tomato fruitworm in 1916. Spaces between horizontal lines represent 100 in case of total number of tomatoes, and 20 in case of percentage wormy. Vertical lines represent weeks. The solid line represents the total number of tomatoes from the unsprayed check; the dotted line, the percentage of check wormy; the line of dashes, the total number of tomatoes from plants sprayed with arsenate of lead; the line of dots and dashes, the percentage of sprayed tomatoes wormy.

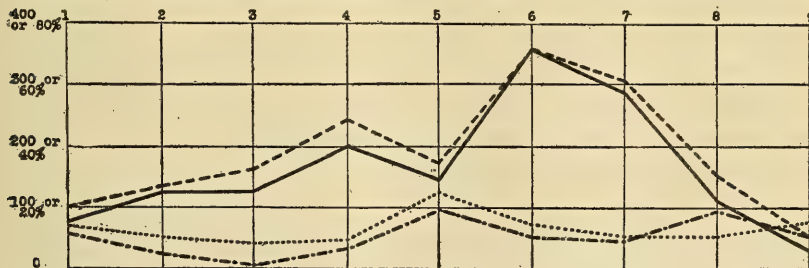


FIG. 5.—Diagram, prepared from weekly totals during harvesting season, showing number of tomatoes of the Globe variety and percentage apparently injured by the tomato fruitworm in 1917. Spaces between horizontal lines represent 100 in case of total number of tomatoes, and 20 in case of percentage wormy. Vertical lines represent weeks. The solid line represents the total number of tomatoes from the unsprayed check; the dotted line, the percentage of check wormy; the line of dashes, the total number of tomatoes from plants sprayed with arsenate of lead; the line of dots and dashes, the percentage of sprayed tomatoes wormy.

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LOGAN WALLER PAGE, Director



Washington, D. C.

PROFESSIONAL PAPER.

August 30, 1918

TYPICAL SPECIFICATIONS FOR NONBITUMINOUS ROAD MATERIALS.

By PRÉVOST HUBBARD, *Chemical Engineer*, and
FRANK H. JACKSON, JR., *Assistant Testing Engineer*.

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INTRODUCTION.

This publication should be considered as a companion bulletin to "Typical Specifications for Bituminous Road Materials."¹ In it are given a number of typical specifications for the more common nonbituminous materials used in the construction and maintenance of various types of highways. These are grouped mainly according to type of road. In so far as practicable materials of the same class have also been kept together. When a single type of road requires more than one class of nonbituminous material peculiarly suited to that class, all of the materials are treated in the same specification under appropriate subheadings. Thus in specification RC-2, where the requirements for coarse aggregate for concrete base are the same for broken stone or gravel, these materials have been specified together. Also in specifications such as RBC-2, for bituminous concrete, all of the nonbituminous constituents, including broken stone, sand, and filler, are included.

During the summer of 1917 a survey was made of stone quarries in certain sections of the country² with the primary object of obtaining data relating to the commercial sizes of broken stone, which would enable the Bureau of Public Roads to recommend a minimum

¹ U. S. Department of Agriculture Bulletin 691.

² "Public Roads," vol. 1, No. 2, June, 1918.

number of standard sizes necessary for the various types of roads in which broken stone is used. It was found that, within a very restricted area, revolving screens, with as many as 28 different size openings, were being used to produce broken stone for a comparatively few types of roads. As a rule, the exact size of product for any one type of road is selected by the individual engineer without reference to other products which the crushing plant may be called upon to supply, also without reference to what size or sizes the engineer himself will select for other types of roads. Moreover, great lack of uniformity in the method of specifying sizes of broken stone was found to exist so that the entire subject of broken stone specifications is at present in an almost chaotic condition.

Following the very logical recommendations of the First Conference of State Highway Testing Engineers and Chemists,¹ the specifications for sizes of broken stone, as given in this bulletin, are based upon laboratory screen tests, rather than upon the size of openings in the commercial screen which produces the material. Based upon data secured in the survey previously mentioned, a limited number of sizes has been selected. It is believed that for the commercial production of each size sufficient tolerance has been allowed in the specifications to make practicable the use of revolving screens with the same openings as the maximum and minimum laboratory screens specified for that size. In most cases, the amount passing an intermediate laboratory screen has also been specified with limits (from 25 to 75 per cent) sufficiently wide to include all acceptable commercial products between the maximum and minimum size but reject most products which would be unacceptable.

The different size broken stone products which may be used satisfactorily in constructing various types of road are given in Table I. It will be seen that not more than five different size openings in revolving screens are required for any one type. In order to meet reasonable working conditions, a general tolerance of not less than 5 per cent retained on the maximum screen, and 15 per cent passing the minimum screen, has been allowed. In the case of screenings, when only the maximum size revolving screen would be required ordinarily, as the product would include dust and all other smaller material, from 40 to 80 per cent of material passing the $\frac{1}{4}$ -inch screen is specified. The only other exception is the broken stone for Topeka type bituminous concrete, where at least 20 per cent of material is required to be retained on the $\frac{1}{4}$ -inch screen.

It is realized that just as satisfactory roads may be constructed with sizes of broken stone varying considerably from these specifications. It is believed, however, that the sizes here covered represent average practice and they are recommended for general use as

a means toward standardizing not only specifications for broken stone but also plant practice in the production of broken stone for highway work.

The forms of specification adopted for broken stone as well as other nonbituminous road materials are, in general, those recommended by the First Conference of State Highway Testing Engineers and Chemists.¹ Following each specification is a brief descriptive paragraph, stating the general conditions governing its uses and what modifications may in certain instances be made. More detailed information and advice relative to methods of construction may be obtained upon application to the Bureau of Public Roads.

It is realized that all classes and types of nonbituminous road materials have not been covered, and it is intended to add to the number of these specifications from time to time. For the convenience of engineers, and in order to make this bulletin complete in itself, the methods of test to which reference is made in the specifications, and directions for sampling, are given in an appendix.

TABLE I.—*Relation of commercial revolving screens to laboratory screen requirements for broken stone.*

Type of road.	Revolving screens.				
	3-inch.	2-inch.	1-inch.	$\frac{3}{4}$ -inch.	$\frac{1}{2}$ -inch.
	Per cent passing laboratory screen of same size.				
Water-bound:					
Bottom course.....	95+	15—			
Top course.....		95+	15—		
Screenings.....			95+		40-80
or					
Base or both courses.....	95+		15—		
Screenings.....			95+		40-80
Cover for bituminous surface treatment:					
Coarse chips.....			95+		15—
or					
Fine chips.....				85+	15—
Bituminous macadam:					
Bottom course.....	95+	15—			
Top course.....		95+	15—		
Chips.....			95+		15—
Screenings.....			95+		40-80
Bituminous macadam:					
Wearing course.....		95+	15—		
Chips.....			95+		15—
Bituminous concrete:					
One-size stone.....			95+		15—
Chips.....				95+	15—
Graded bituminous concrete:					
Coarse aggregate.....			95+		15—
Chips.....				95+	15—
Bituminous concrete (Topeka):					
Broken stone.....				95+	80—
Sheet asphalt:					
Binder stone.....			95+		
Cement concrete pavement:					
Coarse aggregate.....		95+			15—
Cement concrete base:					
Coarse aggregate.....	95+				15—

¹ U. S. Department of Agriculture Bulletin 555.

SPECIFICATION RW-1.

Broken Stone for Water-bound Macadam.

General. The broken stone shall consist of angular fragments of rock, excluding granite, gneiss, sandstone, quartzite, schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter.

The stone shall meet the following requirement:

Physical Properties. French coefficient of wear, not less than----- 7
Screenings. That portion of the product of the crusher, including the dust of fracture, which when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing 1-inch screen-----	100
Total passing $\frac{3}{4}$ -inch screen-----	40 to 80

Top Course Stone. That portion of the product of the crusher which when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing 2-inch screen, not less than-----	95
Total passing $1\frac{1}{2}$ -inch screen-----	25 to 75
Retained on 1-inch screen, not less than-----	85

Bottom Course Stone. That portion of the product of the crusher which when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing 3-inch screen, not less than-----	95
Total passing $2\frac{1}{2}$ -inch screen-----	25 to 75
Retained on 2-inch screen, not less than-----	85

Methods of Testing. Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification is intended to cover stone to be used in the construction of a broken-stone road by the usual water-bound macadam methods. In certain instances the use of granite, gneiss, sandstone, or quartzite may be allowed in the bottom course, provided the material otherwise meets the specification. These types would be excluded from the wearing course, owing to lack of binding qualities found in materials of this nature. The French coefficient of wear of 7.0 is to be considered here in the light of a minimum requirement under rather light traffic conditions, unless the road is to be maintained with a bituminous wearing mat or carpet. The exact value to be inserted should be governed by the character of available material and estimated traffic conditions. For an ordinary water-bound road subjected to moderate traffic, a coefficient of from 9 to 15 would be more satisfactory, while for heavy traffic a value as high as 16.0 might be required. A coefficient of wear of not less than 7.0 is satisfactory when the road surface is to be maintained with a bituminous material.

It is estimated that for an average rock a bottom course 5 inches and a wearing course 3 inches in thickness, before consolidation, will utilize practically the entire product of an ordinary portable crushing outfit and provide sufficient screenings to properly bind the surface, with a slight excess of screenings in the case of the softer grades of rock, which may be used if desired in filling the bottom course.

SPECIFICATION RW-2.

Broken Stone for Water-bound Base.

The broken stone shall consist of angular fragments of rock, excluding **General.** granite, gneiss, sandstone, quartzite, schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter.

The stone shall meet the following requirement:

**Physical
Properties.**

French coefficient of wear, not less than----- 5

That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:

Screenings.

Per cent.

Passing 1-inch screen, not less than----- 95

Total passing $\frac{1}{4}$ -inch screen----- 40 to 80

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

**Coarse
Stone.**

Passing 3-inch screen, not less than----- 95

Total passing 2-inch screen----- 25 to 75

Retained on 1-inch screen, not less than----- 85

Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods: **Methods of
Testing.**

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.

2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification provides primarily for stone to be used in the construction of water-bound base upon which some higher type of wearing course will be placed, preferably after the base has been finally compacted by traffic. For the softer grades of rock it may also serve for both foundation and wearing courses, provided the thickness of each is not less than 4 inches. In case the broken-stone base is not to be water bound, granite, gneiss, sandstone, and quartzite may be allowed.

SPECIFICATION RS-1.

Coarse Broken Stone for Bituminous Surface Treatment.

The broken stone shall consist of angular fragments of clean, hard, **General.** tough, durable rock of uniform quality throughout, free from soft or disintegrated stone, dirt, or other objectionable matter.

It shall be that product of the crusher, which when tested by means of laboratory screens, will meet the following requirements:

Per cent.

Passing 1-inch screen, not less than----- 95

Retained on $\frac{1}{4}$ -inch screen, not less than----- 85

Tests of the size of broken stone shall be made in accordance with the following method: **Method of
Testing.**

Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification provides for a broken-stone product which may be used as cover for a bituminous material applied hot to a road surface. For this purpose it should be evenly spread at the rate of 1 cubic yard to every 50 to 75 square yards of treated road surface, depending upon the amount of bituminous material which has been applied per square yard. Under traffic, preferably preceded by rolling, it is expected to produce, in combination with the bituminous material, a wearing mat or carpet. When the treatment of bituminous material is less than $\frac{1}{2}$ gallon per square yard a product meeting Specification RS-2 is to be preferred.

SPECIFICATION RS—2.

*Fine Broken Stone or Gravel for Bituminous Surface Treatment.***General.**

The broken stone or gravel shall consist of clean hard tough durable stone, free from soft or disintegrated particles, dirt, or other objectionable matter.

Size.

When tested by means of laboratory screens it shall meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch screen, not less than.....	85
Retained on $\frac{1}{2}$ -inch screen, not less than.....	85

Method of Testing.

Tests of the size of broken stone or gravel shall be made in accordance with the following method:

Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification provides for a product to be used as cover for a bituminous material applied to a road surface. For this purpose 1 cubic yard should cover from 50 to 150 square yards of treated road surface, depending upon the amount of bituminous material which has been applied per square yard. Under traffic it is expected to produce, in combination with the bituminous material, a thin wearing mat or carpet. It may be considered as an alternate for Specification RS-1 and preferable to the latter when the treatment of bituminous material is less than $\frac{1}{2}$ gallon per square yard.

SPECIFICATION RB-1.

*Broken Stone for Bituminous Macadam.***General.**

The broken stone shall consist of angular fragments of rock, excluding granite, gneiss, sandstone, quartzite, schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Physical Properties.

The stone shall meet the following requirements:

Screenings.

French coefficient of wear, not less than..... 7

That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than.....	95
Total passing $\frac{1}{2}$ -inch screen.....	40 to 80

Chips.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than.....	95
Retained on $\frac{1}{2}$ -inch screen, not less than.....	85

Top Course Stone.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 2-inch screen, not less than.....	95
Total passing $1\frac{1}{2}$ -inch screen.....	25 to 75
Retained on 1-inch screen, not less than.....	85

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.	
Passing 3-inch screen, not less than-----	95	
Total passing 2½-inch screen-----	25 to 75	
Retained on 2-inch screen, not less than-----	85	

Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods: **Methods of Testing.**

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification is intended to cover stone to be used in the construction of a water-bound broken-stone base, and a bituminous broken-stone wearing course constructed by the penetration method. If the base is not to be water bound, the use of granite, gneiss, sandstone, or quartzite may be allowed, provided the material otherwise meets the specifications. Practically the entire output of an ordinary portable crushing outfit will be utilized if a bottom course filled with screenings is constructed 5 inches thick and a top course from 2½ to 3 inches thick. The chips should be used to fill the surface voids in the top course after the first application of bituminous material has been made and also as a cover for the second application or seal coat. Such roads may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS-1 or RS-2.

SPECIFICATION RB-2.

Broken Stone for Bituminous Macadam Wearing Course.

The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, of uniform quality throughout, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone. **General.**

The stone shall meet the following requirement:

French coefficient of wear, not less than-----	7	Physical Properties.
--	---	-----------------------------

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: **Chips.**

	Per cent.	
Passing 1-inch screen, not less than-----	95	
Retained on ¾-inch screen, not less than-----	85	

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements: **Coarse Stone.**

	Per cent.	
Passing 2-inch screen, not less than-----	95	
Total passing 1½-inch screen-----	25 to 75	
Retained on 1-inch screen, not less than-----	85	

Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods: **Methods of Testing.**

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification covers stone to be used in the construction of a bituminous broken-stone wearing course in which the bituminous material is applied by the penetration method. The maximum size

of 2 inches specified for the wearing course is on the basis of a course $2\frac{1}{2}$ to 3 inches in thickness after consolidation. The chips should be used to fill the surface voids after the first application of bituminous material has been made and also as a cover for the second application or seal coat. Roads of this type may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS-1 or RS-2.

SPECIFICATION RBC-1.

Broken Stone for One-size Stone Bituminous Concrete Wearing Course.

General.

The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Physical Properties.

The stone shall meet the following requirements:

French coefficient of wear, not less than-----	8
Toughness, not less than-----	8

Chips.

That portion of the product of the crusher, which, when tested by means of laboratory screens will meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch screen, not less than-----	95
Retained on $\frac{1}{2}$ -inch screen, not less than-----	85

Aggregate.

That portion of the product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing 1-inch screen, not less than-----	95
Total passing $\frac{3}{4}$ -inch screen-----	25 to 75
Retained on $\frac{3}{4}$ -inch screen, not less than-----	85

Methods of Testing.

Tests of the physical properties of the rock and of the sizes of broken-stone products shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Toughness, U. S. Department of Agriculture Bulletin 347, p. 15.
3. Size, U. S. Department of Agriculture Bulletin 555, p. 32.

This specification is intended to cover stone to be used in the construction of a bituminous concrete wearing course and seal coat. The broken stone aggregate for the concrete proper is a single size of crusher product with no exact grading limitations. It may therefore produce what is commonly known as an open mix, and will carry from 5 to 7 per cent bitumen. Such mixture may be placed on a well-compacted broken stone or gravel foundation or a cement-concrete foundation so as to produce after rolling a wearing course 2 inches in depth. A seal coat of bituminous material should then be applied and covered with chips in sufficient quantity to take up all excess of bitumen. Such roads may be maintained with surface treatments of bituminous materials, covered with material conforming to Specification RS-2.

SPECIFICATION RBC-2.

Broken Stone, Sand, and Filler for Coarse Aggregate Bituminous Concrete Wearing Course.

BROKEN STONE.

The broken stone shall consist of angular fragments of rock, excluding General schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

The stone shall meet the following requirements:

French coefficient of wear, not less than-----	8	Physical Properties.
Toughness, not less than-----	8	

That portion of the product of the crusher, which, when tested by Chips. means of laboratory screens, will meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch screen, not less than-----	95
Retained on $\frac{1}{2}$ -inch screen, not less than-----	85

That portion of the product of the crusher, which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.	Coarse Aggregate.
Passing 1-inch screen, not less than-----	95	
Total passing $\frac{3}{4}$ -inch screen-----	25 to 75	
Retained on $\frac{3}{4}$ -inch screen, not less than-----	85	

SAND.

The sand for fine aggregate shall be composed of sound, durable stone General particles, free from a coating of clay or loam.

When tested by means of laboratory screens the sand shall meet the Grading. following requirements:

	Per cent.
Passing $\frac{1}{4}$ -inch screen-----	100
Total passing 40-mesh sieve-----	30 to 70
Retained on 200-mesh sieve, not less than-----	90

MINERAL FILLER.

The mineral filler shall consist of limestone dust, dolomite dust, Port- General land cement, or natural cement. It shall be free from foreign or other objectionable material.

When tested by means of laboratory sieves, the mineral filler shall meet Fineness. the following requirements:

	Per cent.
Passing 30-mesh sieve-----	100
Total passing 200-mesh sieve, not less than-----	65

Tests of the physical properties of the rock and of the size or mechanical analysis of broken stone, sand, and mineral filler shall be made in Methods of Testing. accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 5.
2. Toughness, U. S. Department of Agriculture Bulletin 347, p. 15.
3. Size of broken stone, U. S. Department of Agriculture Bulletin 555, p. 32.
4. Mechanical analysis of sand and mineral filler, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the mineral constituents of a roughly proportioned bituminous concrete consisting of from 45 to 60 per cent broken stone coarse aggregate, from 30 to 45 per cent sand (fine aggregate), from 3 to 5 per cent mineral filler, and from 5 to 8 per cent bitumen. Such a concrete is similar in character to that described under Specification RBC-1, but is a closer mix. It should preferably be placed upon a cement concrete foundation

so as to produce, after rolling, a wearing course 2 inches in depth. A seal coat of bituminous material should then be applied and covered with chips in sufficient quantity to take up all excess of bitumen. Such roads may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS-2.

SPECIFICATION RBC-3.

Broken Stone, Sand, and Filler for Fine Aggregate Bituminous Concrete Wearing Course.

BROKEN STONE.

General. The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone.

Size. It shall be that product of the crusher which, when tested by means of laboratory screens, will meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch screen, not less than-----	95
Retained on $\frac{1}{4}$ -inch screen, not less than-----	20

SAND.

General. The sand shall be composed of sound durable-stone particles, free from a coating of clay or loam.

Size. When tested by means of laboratory screens the sand shall meet the following requirements:

	Per cent.
Passing $\frac{1}{4}$ -inch screen-----	100
Retained on 200-mesh sieve, not less than-----	90

MINERAL FILLER.

General. The mineral filler shall consist of limestone, dust, dolomite dust, Portland cement, or natural cement. It shall be free from foreign or other objectionable material.

Fineness. When tested by means of laboratory sieves, the mineral filler shall meet the following requirements:

	Per cent.
Passing 30-mesh sieve-----	100
Total passing 200-mesh sieve, not less than-----	65

TOTAL MINERAL AGGREGATE.

General. The total mineral aggregate shall consist of a uniform mixture of the broken stone, sand, and mineral filler, the required grading of each being such as to produce, when properly proportioned, a mixture conforming to the following limitations for grading. The exact proportion of each constituent producing a total mineral aggregate within these limitations shall be as directed by the engineer.

Grading. When tested by means of laboratory screens and sieves the total mineral aggregate shall meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch and retained on $\frac{1}{4}$ -inch screen-----	5 to 10
Passing $\frac{1}{4}$ -inch screen and retained on 10-mesh sieve-----	11 to 25
Passing 10-mesh and retained on 40-mesh sieve-----	7 to 25
Passing 40-mesh and retained on 80-mesh sieve-----	11 to 36
Passing 80-mesh and retained on 200-mesh sieve-----	10 to 25
Passing 200-mesh sieve-----	5 to 11

Tests of the size or mechanical analysis of broken stone, sand, and mineral filler shall be made in accordance with the following methods: **Methods of Testing.**

1. Size of broken stone, U. S. Department of Agriculture Bulletin 555, p. 32.
2. Mechanical analysis of sand and mineral filler, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Grading of total mineral aggregate, U. S. Department of Agriculture Bulletin 555, pp. 32 and 33.

—

This specification is intended to cover the mineral constituents and grading for bituminous concrete of a modified Topeka, or stone-filled, sheet asphalt type. It is so drawn that from 10 to 50 per cent of broken stone will be required and the mixture of very fine broken stone and sand will possess a satisfactory sheet asphalt grading. Such an aggregate will carry from 7 to 11 per cent of bitumen. It should preferably be placed upon a cement concrete foundation to a compacted depth of 2 inches. No seal coat will ordinarily be required, and maintenance should consist only in patching with bituminous concrete until it is necessary to replace the entire wearing course.

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SPECIFICATION RBC-4.

Broken Stone, Sand, and Filler for Binder Course and Sheet Asphalt Wearing Course.

BROKEN STONE FOR BINDER COURSE.

The broken stone shall consist of angular fragments of rock, excluding schist, shale, and slate, free from thin or elongated pieces, soft or disintegrated stone, dirt, or other objectionable matter, occurring either free or as a coating on the stone, and when tested all of the broken stone shall pass a 1-inch laboratory screen.

The stone shall meet the following requirement:

Toughness, not less than.....	8	Physical Properties.
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SAND FOR BINDER COURSE.

The sand shall be composed of sound durable stone particles, free from a coating of clay and loam, which when tested shall all pass a $\frac{1}{2}$ -inch laboratory screen.

TOTAL MINERAL AGGREGATE FOR BINDER COURSE.

The total mineral aggregate shall consist of a uniform mixture of broken stone and sand, the required grading of each being such as to produce, when properly proportioned, a mixture conforming to the following limitations for grading. The exact proportion of each constituent producing a mineral aggregate within these limitations shall be as directed by the engineer.

When tested by means of laboratory screens and sieves the total mineral aggregate shall meet the following requirements:

	Per cent.
Passing 1-inch and retained on $\frac{1}{2}$ -inch screen.....	15 to 65
Passing $\frac{1}{2}$ -inch screen and retained on 10-mesh sieve.....	20 to 50
Passing 10-mesh sieve.....	15 to 35

SAND FOR SHEET-ASPHALT WEARING COURSE.

General. The sand shall be composed of sound, durable, angular stone particles, free from a coating of clay or loam.

Grading. When tested by means of laboratory sieves the sand shall meet the following requirements:

	Per cent.
Passing 10-mesh sieve-----	100
Total passing 10-mesh and retained on 40-mesh sieve-----	12 to 50
Passing 10-mesh and retained on 20-mesh sieve-----	2 to 15
Passing 20-mesh and retained on 30-mesh sieve-----	5 to 15
Passing 30-mesh and retained on 40-mesh sieve-----	5 to 25
Passing 40-mesh and retained on 50-mesh sieve-----	5 to 30
Passing 50-mesh and retained on 80-mesh sieve-----	5 to 40
Total passing 80-mesh and retained on 200-mesh sieve-----	20 to 40
Passing 80-mesh and retained on 100-mesh sieve-----	6 to 20
Passing 100-mesh and retained on 200-mesh sieve-----	10 to 25
Passing 200-mesh sieve-----	0 to 5

MINERAL FILLER FOR SHEET-ASPHALT WEARING COURSE.

General. The mineral filler shall consist of limestone dust, dolomite dust, Portland cement, or natural cement. It shall be free from foreign or other objectionable material.

Fineness. When tested by means of laboratory sieves, the mineral filler shall meet the following requirements:

	Per cent.
Passing 30-mesh sieve-----	100
Total passing 200-mesh sieve, not less than-----	65

Methods of Testing.

Tests of the physical properties of the rock and of the size, mechanical analysis, or grading of broken stone, sand, and mineral filler shall be made in accordance with the following methods:

1. Toughness, U. S. Department of Agriculture Bulletin 347, p. 15.
2. Size of broken stone, U. S. Department of Agriculture Bulletin 555, p. 32.
3. Mechanical analysis or grading of sand and mineral filler, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the mineral constituents and rough grading of the mineral aggregate of a binder course and the sand and mineral filler for a sheet-asphalt wearing course. The gradings are essentially those included in Specifications for Sheet Asphalt Paving adopted by the American Society of Municipal Improvements in 1915. The aggregate for binder course will carry from 4 to 7 per cent bitumen. It should be laid upon a concrete base so as to produce a thickness after compaction of about $1\frac{1}{2}$ inches.

In order to secure the specified sand grading for the wearing course it may be necessary to combine two or more sands in predetermined proportions. The surface mixture should be composed of sand, mineral filler, and asphalt cement. It should carry from 6 to 20 per cent filler and from $9\frac{1}{2}$ to $13\frac{1}{2}$ per cent bitumen. It should be laid upon the binder course so as to produce a compacted wearing course $1\frac{1}{2}$ or 2 inches thick as desired. Maintenance of the wearing course should consist only in patching with sheet asphalt topping until it is necessary to replace the entire course.

SPECIFICATION RC-1.

Broken Stone and Sand for One-course Portland Cement Concrete Pavement.

BROKEN STONE FOR COARSE AGGREGATE.

The broken stone shall consist of fragments of clean durable crushed **General.** rock, free from soft, thin, elongated or laminated pieces, disintegrated stone, vegetable, or other deleterious matter.

The stone shall meet the following requirements:

	Physical Properties.
French coefficient of wear not less than-----	8
Toughness, not less than-----	8

When tested by means of laboratory screens the broken stone for coarse **Grading.** aggregate shall meet the following requirements:

	Per cent.
Passing 2-inch screen, not less than-----	95
Total passing 1-inch screen-----	40 to 75
Retained on $\frac{1}{2}$ -inch screen, not less than-----	85

SAND FOR FINE AGGREGATE.

The sand shall consist of clean, hard, durable, uncoated stone particles, **General.** preferably siliceous, free from lumps of clay, soft or flakey particles, loam, and all organic matter.

It shall be well graded from coarse to fine, and when tested by means **Grading.** of laboratory screens and sieves shall meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch screen-----	100
Total passing 20-mesh sieve-----	50 to 80
Total passing 50-mesh sieve, not more than-----	20
Passing 100-mesh sieve, not more than-----	5

Not more than 3 per cent by weight shall be removed by the elutriation test.

When the sand is mixed with Portland cement in the proportion of 1 **Mortar Strength** part of cement to 3 parts of sand, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 100 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

Tests of the physical properties of the rock, the grading or mechanical **Methods of** analysis of broken stone and sand, and of the mortar tensile strength of **Testing.** sand shall be made in accordance with the following methods:

1. Toughness: U. S. Department of Agriculture Bulletin 347, page 15.
2. Grading of Broken Stone: U. S. Department of Agriculture Bulletin 555, page 32.
3. Mechanical Analysis of Sand: U. S. Department of Agriculture Bulletin 555, page 33.
4. Elutriation Test for Sand: U. S. Department of Agriculture Bulletin 555, page 32.
5. Mortar Tensile Strength Test for Sand: A. S. T. M. Standard Test C9-17.

This specification provides for coarse and fine aggregate to be used in the construction of a one-course Portland cement concrete pavement. While a coefficient of hardness of not less than 16 for the stone for coarse aggregate might well be included under physical properties, a requirement for French coefficient of wear has been used instead, owing to the fact that few laboratories are equipped with a Dorry hardness machine.

The 15 per cent of coarse aggregate passing the $\frac{1}{2}$ -inch screen, which is allowed, is permissible only upon the assumption that

construction specifications will be based upon a fixed proportion of cement to combined coarse and fine aggregate and that the relative amounts of broken stone and sand will be varied as directed by the engineer so as to approximate definite proportions of coarse and fine aggregate. Thus the concrete should be composed of 1 part of Portland cement and $4\frac{1}{2}$ parts of fine and coarse aggregate, each measured separately and accurately by volume. The concrete should approximate a $1:1\frac{1}{2}:3$ mix, but the engineer should vary the relative proportions of fine and coarse aggregate, depending upon their exact grading so as to obtain a concrete of maximum density.

The concrete should be mixed in a batch mixer for not less than $1\frac{1}{2}$ minutes and the water should be reasonably clear, free from oil, acid, alkali, or vegetable substance, and neither brackish nor salt. Sufficient water should be used to produce a concrete which will flatten out and quake when deposited in place, but not enough to cause it to flow or to separate mortar and coarse aggregate.

SPECIFICATION RC-2.

Broken Stone or Gravel, and Sand for Portland Cement Concrete Base.

BROKEN STONE OR GRAVEL FOR COARSE AGGREGATE.

General.

The broken stone or gravel for coarse aggregate shall consist of clean, hard, tough, durable stone. It shall be free from soft, thin, elongated, or laminated pieces, disintegrated stone, vegetable, or other deleterious matter.

Grading.

When tested by means of laboratory screens the coarse aggregate shall meet the following requirements:

	Per cent.
Passing 3-inch screen, not less than-----	95
Total passing $1\frac{1}{2}$ -inch screen-----	40 to 75
Retained on $\frac{3}{4}$ -inch screen, not less than-----	85

SAND FOR FINE AGGREGATE.

General.

The sand shall consist of clean, hard, durable, uncoated stone particles, preferably siliceous, free from lumps of clay, soft or flakey particles, loam, and all organic matter.

Grading.

It shall be well graded from coarse to fine, and when tested by means of laboratory screens and sieves shall meet the following requirements:

	Per cent.
Passing $\frac{1}{4}$ -inch screen-----	100
Total passing 20-mesh sieve, not less than-----	20
Total passing 50 mesh sieve, not more than-----	50
Passing 100 mesh sieve, not more than-----	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

Mortar Strength Test.

When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand, by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

Tests of the grading or mechanical analysis of broken stone or gravel, and sand, and of the mortar tensile strength of sand shall be made in accordance with the following methods: **Methods of Testing.**

1. Grading of broken stone or gravel, U. S. Department of Agriculture Bulletin 555, p. 32. (8)
2. Mechanical analysis of sand, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Elutriation test for sand, U. S. Department of Agriculture Bulletin 555, p. 32.
4. Mortar tensile strength test for sand, A. S. T. M., Standard Test C9-17.

This specification provides for coarse and fine aggregate to be used in the construction of a Portland cement concrete base.

The 15 per cent of coarse aggregate passing the $\frac{1}{4}$ -inch screen which is allowed is only permissible upon the assumption that construction specifications will be based upon a fixed proportion of cement to combined coarse and fine aggregate and that the relative amounts of broken stone or gravel and sand will be varied as directed by the engineer so as to approximate definite proportions of coarse and fine aggregate. Thus the concrete should be composed of 1 part of Portland cement and 9 parts of fine and coarse aggregate, each measured separately and accurately by volume. The concrete should approximate a 1:3:6 mix, but the engineer should vary the relative proportions of fine and coarse aggregate depending upon their exact grading, so as to obtain a concrete of maximum density.

The concrete should be mixed in a batch mixer for not less than 1 minute and the water should be reasonably clear, free from oil, acid, alkali, or vegetable substance, and neither brackish nor salt. Sufficient water should be used to produce a concrete which will flatten out and quake when deposited in place, but not enough to cause it to flow or to separate mortar and coarse aggregate.

SPECIFICATION GW-1.

Gravel for Water-bound Gravel Roads.

General.

The gravel shall be composed of fragments of hard, durable rock, of high resistance to abrasion, together with sand and clay or other binding material, and shall be free from thin or elongated pieces.

Quality.

	Per cent.
Cementing value of material under $\frac{1}{4}$ -inch mesh shall be not less than-----	50
1. For base course:	
(a) The gravel, when tested by means of laboratory screens, shall meet the following requirements:	
Passing a 3-inch screen, not less than-----	95
Total retained on $\frac{1}{4}$ -inch screen-----	50 to 75
(b) The material retained on the $\frac{1}{4}$ -inch screen is known as coarse aggregate. The coarse aggregate, when tested by means of a laboratory screen, shall meet the following requirement:	
Total retained on $1\frac{1}{2}$ -inch screen-----	25 to 75
(c) The material passing the $\frac{1}{4}$ -inch screen is known as fine aggregate. The fine aggregate, when tested by means of a laboratory sieve, shall meet the following requirement:	
Total passing 200-mesh sieve-----	15 to 35
2. For wearing course:	
(a) The gravel, when tested by means of laboratory screens, shall meet the following requirements:	
Passing a 2-inch screen, not less than-----	95
Total retained on $\frac{1}{4}$ -inch screen-----	50 to 75
(b) The material retained on the $\frac{1}{4}$ -inch screen is known as coarse aggregate. The coarse aggregate, when tested by means of a laboratory screen, shall meet the following requirement:	
Total retained on 1-inch screen-----	25 to 75
(c) The material passing the $\frac{1}{4}$ -inch screen is known as fine aggregate. The fine aggregate, when tested by means of a laboratory sieve, shall meet the following requirement:	
Total passing 200-mesh sieve-----	15 to 35

Method of Testing.

Tests of the quality and grading of the gravel shall be made in accordance with the following methods:

Cementing value, U. S. Department of Agriculture Bulletin 345, p. 19.
Grading, U. S. Department of Agriculture Bulletin 555, p. 32 (9).

This specification covers the quality and grading of a sand-clay-gravel suitable for use in the construction of a water-bound gravel road. It applies to gravels composed mainly of fragments of quartz or other nonbinding rock types. In cases where the gravel is composed essentially of limestone or other materials which will bond under traffic, considerably less material under 200-mesh may be allowed. The sizes specified contemplate a base course of at least 4 inches, and a wearing course of at least 3 inches in thickness after consolidation. The relative proportions of the various intermediate sizes have been drawn so as to exclude only gravels of manifestly poor grading. In cases where the gravel, although otherwise acceptable, is deficient in sand or clay, such materials, if available, and of a suitable character, may be added in sufficient quantities to bring the grading and cementing value of the gravel to within the limits specified. This should be done by spreading the sand or clay uniformly over the loose gravel surface and thoroughly harrowing with a spike-tooth harrow, after which the surface is consolidated.

In maintaining roads of this type, material as nearly the same as that composing the road surface should be used. In patching, care should be taken that the finished surface after consolidation is smooth and continuous.

SPECIFICATION GBC-2.

Gravel, Sand, and Filler for Coarse Aggregate Bituminous Concrete Wearing Course.

GRAVEL.

The gravel shall be composed of sound, hard, durable fragments of **General** rock of high resistance to abrasion and shall contain no particles of shale, slate, coal, or other materials which easily disintegrate. It shall be free from vegetable or other deleterious matter, and shall contain no soft, thin, or elongated pieces.

The pea gravel, when tested by means of laboratory screens, shall **Pea Gravel** meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch screen, not less than-----	95
Retained on $\frac{1}{2}$ -inch screen, not less than-----	85

The coarse aggregate, when tested by means of laboratory screens, shall meet the following requirements: **Coarse Aggregate.**

	Per cent.
Passing 1-inch screen, not less than-----	95
Total passing $\frac{3}{4}$ -inch screen-----	25 to 75
Retained on $\frac{3}{4}$ -inch screen, not less than-----	85

SAND.

The sand for fine aggregate shall be composed of sound, durable stone **General** particles, free from a coating of clay or loam.

When tested by means of laboratory screens and sieves, the sand shall **Grading** meet the following requirements:

	Per cent.
Passing $\frac{1}{2}$ -inch screen-----	100
Total passing 40-mesh sieve-----	30 to 70
Retained on 200 mesh sieve, not less than-----	90

MINERAL FILLER.

The mineral filler shall consist of limestone dust, dolomite dust, Portland cement, or natural cement. It shall be free from foreign or other objectionable material. **General.**

When tested by means of laboratory sieves, the mineral filler shall **Fineness** meet the following requirements:

	Per cent.
Passing 30 mesh sieve-----	100
Total passing 200 mesh sieve, not less than-----	65

Tests of the grading of the gravel, sand, and filler shall be made in **Methods of Testing.** accordance with the following methods:

Grading of Gravel, U. S. Department of Agriculture Bulletin 555, p. 32.
Grading of Sand and Mineral Filler, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the mineral constituents of a roughly proportioned bituminous concrete consisting of from 45 to 60 per cent gravel or coarse aggregate, from 30 to 45 per cent sand or fine aggregate, from 3 to 5 per cent mineral filler, and from 5 to 8 per cent bitumen. This mixture should preferably be

placed upon a cement concrete foundation so as to produce, after rolling, a wearing course 2 inches in depth. A seal coat of bituminous material should then be applied and covered with pea gravel in sufficient quantity to take up all excess of bitumen.

Such roads may be maintained with surface treatments of bituminous material, covered with material conforming to Specification RS-2.

SPECIFICATION SgW 2.

Slag for Water-Bound Base.

General.	The broken slag shall consist of angular fragments, reasonably uniform in density and quality, free from metallic iron, thin or elongated pieces, dirt, or other objectionable matter.	
Physical Properties.	The slag shall meet the following requirements:	
	Weight in pounds per cubic foot, each size specified, not less than—	70
	French coefficient of wear, not less than—	5.
Screenings.	That portion of the product of the crusher, including the dust of fracture, which, when tested by means of laboratory screens, will meet the following requirements:	
		Per cent.
	Passing 1-inch screen, not less than—	95
	Total passing ¾-inch screen—	40 to 80
Coarse Slag.	That portion of the product of the crusher, which, when tested by means of laboratory screens, will meet the following requirements:	
		Per cent.
	Passing 3-inch screen, not less than—	95
	Total passing 2-inch screen—	25 to 75
	Retained on 1-inch screen, not less than—	85
Methods of Testing.	The tests of the physical properties and sizes of the slag shall be made in accordance with the following methods:	
	1. Weight per Cubic Foot, U. S. Department of Agriculture Bulletin 555, p. 32 (6).	
	2. French Coefficient of Wear, U. S. Department of Agriculture Bulletin 347, p. 5.	
	3. Grading, U. S. Department of Agriculture Bulletin 555, p. 32 (8).	

This specification provides primarily for slag to be used in the construction of a water-bound base upon which some higher type of wearing course will be placed, preferably after the base has been finally compacted by traffic. For a light traffic road it may also serve for both foundation and wearing course, provided the thickness of each is not less than 4 inches.

SPECIFICATION Sd-1.

Natural Sand Clay or Topsoil Mixtures for Road Surfacing.

The sand clay or topsoil shall be composed of a uniform mixture of **General.** hard durable fragments of sand, together with silt and clay, and may advantageously carry a considerable amount of gravel. The mixture should be free from an excess of feldspar or mica.

Cementing value of material under $\frac{1}{4}$ inch shall be not less than--- 35 **Quality.**

The material which will pass a 10-mesh sieve when tested by means of **Grading.** laboratory sieves shall meet the following requirement for grading:

	Per cent.
Clay -----	10 to 25
Silt -----	10 to 25
Total sand-----	50 to 80

Tests of the cementing value and grading of the sand clay or topsoil shall be made in accordance with the following methods: **Methods of Testing.**

Cementing value, U. S. Department of Agriculture Bulletin 347, p. 19.

Grading, U. S. Department of Agriculture Bulletin 555, p. 33.

This specification is intended to cover the quality and approximate grading of natural sand clay and topsoil mixtures for use particularly in the South Atlantic States.

The limits of sizes are drawn so as to exclude only sand clay and topsoil of manifestly inferior grading. Where heavy traffic is to be expected, and likewise in cases where the available material warrants, the minimum allowable percentage of sand should be increased and the corresponding maximum allowable percentage of both clay and silt decreased. In cases where it is desired to construct a sand-clay road by admixing sand and clay in place, the amounts of each to be incorporated should be so gauged that the combined material, after thorough mixing, will grade approximately within the limits here shown.

The maintenance of a sand-clay road should be continuous. Patching should be done with material as nearly like that used in the original surface as possible.

SPECIFICATION C4-1.

*Portland Cement.***Definition.**

(1) Portland cement is the product obtained by finely pulverizing clinker produced by calcining to incipient fusion an intimate and properly proportioned mixture of argillaceous and calcareous materials, with no additions subsequent to calcination except water and calcined or uncalcined gypsum.

I. CHEMICAL PROPERTIES.

Chemical Limits.

(2) The following limits shall not be exceeded :

	Per cent.
Loss on ignition -----	4.00
Insoluble residue -----	.85
Sulphuric anhydride (SO_3) -----	2.00
Magnesia (MgO) -----	5.00

II. PHYSICAL PROPERTIES.

Specific Gravity.

(3) The specific gravity of cement shall be not less than 3.10. Should the test of cement as received fall below this requirement, a second test may be made upon an ignited sample. The specific-gravity test will not be made unless specifically ordered.

Fineness.

(4) The residue on a standard 200 mesh sieve shall not exceed 22 per cent by weight.

Soundness.

(5) A pat of neat cement shall remain firm and hard, and show no signs of distortion, cracking, checking, or disintegration in the steam test for soundness.

Time of Setting.

(6) The cement shall not develop initial set in less than 45 minutes when the Vicat needle is used, or 60 minutes when the Gillmore needle is used. Final set shall be attained within 10 hours.

Tensile Strength.

(7) The average tensile strength in pounds per square inch of not less than three standard mortar briquets composed of 1 part cement and 3 parts standard sand, by weight, shall be equal to or higher than the following :

Age at test.	Storage of briquets.	Tensile strength per square inch.
<i>Days.</i>		<i>Pounds.</i>
7	1 day in moist air, 6 days in water.	200
28	1 day in moist air, 27 days in water.	300

(8) The average tensile strength of standard mortar at 28 days shall be higher than the strength at 7 days.

III. PACKAGES, MARKING, AND STORAGE.

Packages and Marking.

(9) The cement shall be delivered in suitable bags or barrels with the brand and name of the manufacturer plainly marked thereon, unless shipped in bulk. A bag shall contain 94 pounds net. A barrel shall contain 376 pounds net.

Storage.

(10) The cement shall be stored in such a manner as to permit easy access for proper inspection and identification of each shipment, and in a suitable weather-tight building which will protect the cement from dampness.

IV. INSPECTION.

Inspection.

(11) Every facility shall be provided the purchaser for careful sampling and inspection either at the mill or at the site of the work, as may

be specified by the purchaser. At least 10 days from the time of sampling shall be allowed for the completion of the 7-day test; and at least 31 days shall be allowed for the completion of the 28-day test. The 28-day test shall be waived only when specifically ordered.

V. REJECTION.

Rejection.

(12) The cement may be rejected if it fails to meet any of the requirements of these specifications.

(13) Cement shall not be rejected on account of failure to meet the fineness requirement if, upon retest after drying at 100° C. (212° F.) for one hour it meets this requirement.

(14) Cement failing to meet the test for soundness in steam may be accepted if it passes a retest using a new sample at any time within 28 days thereafter.

(15) Packages varying more than 5 per cent from the specified weight may be rejected; and if the average weight of packages in any shipment, as shown by weighing 50 packages taken at random, is less than that specified, the entire shipment may be rejected.

The cement shall be tested in accordance with the following methods: **Methods of Testing.**
Tests for Portland cement, A. S. T. M. Standard, C9-17.

This is the United States Government specification for Portland cement, as described in Bureau of Standards Circular No. 33. It is also Standard Specification C9-17 of the American Society for Testing Materials. It is intended to apply wherever Portland cement is used.

SPECIFICATION Br-1.

Vitrified Paving Brick, Cushion Sand, and Grouting Sand for Brick Pavement.

VETRIFIED PAVING BRICK.

All brick shall be of a size commercially known as four-inch brick. **General.** They shall be thoroughly annealed, tough and durable, regular in size and shape, and evenly burned. When broken, the brick shall show a dense, stonelike body, free from lime, air pockets, cracks, or marked laminations. Kiln marks shall not exceed $\frac{1}{8}$ of an inch, and the wearing surface shall show but slight kiln marks.

Representative samples of the brick shall meet the following require- **Rattler Test.**
ments when subjected to the rattler test:

Average loss by abrasion on one or more samples, not more than 22 per cent.

Maximum difference in per cent loss by abrasion when more than one representative sample is tested, not more than 8 per cent, provided, however, that no sample shall show more than 24 per cent loss.

A maximum of three tests may be used as a basis for rejection.

The brick shall meet the following requirements:

Dimensions.

	Inches.
Length-----	8½ to 9½
Width-----	3½ to 3½
Depth-----	3½ to 4½

Variations among brick from a single plant shall not exceed the following limits:

	Inch.
Variation in length-----	$\frac{1}{8}$
Variation in width-----	$\frac{1}{8}$
Variation in depth-----	$\frac{1}{8}$

If the edges of the brick are rounded, the radius shall not exceed $\frac{1}{16}$ of an inch.

Only bricks with lugs or projections on one side, raised not less than $\frac{1}{8}$ of an inch, nor more than $\frac{1}{4}$ of an inch, shall be used.

The ends of the brick shall have either a semicircular groove with a radius of not less than $\frac{1}{8}$ of an inch nor more than $\frac{1}{4}$ of an inch, or a bulge of at least $\frac{1}{16}$ of an inch.

The name or trade-mark of the manufacturer, if shown on the brick, shall be recessed and not raised.

**Visual
Inspection.**

The brick shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject upon variations from the general and dimensions clauses and upon the following grounds:

All brick which are broken through, or chipped in such manner that neither wearing surface remains substantially intact, or in such manner that the lower or bearing surface is reduced in area by more than one-eighth.

All brick which are cracked to a depth greater than $\frac{1}{8}$ inch on any surface, or which are cracked on the wearing surface.

All brick which are so offsize or so misshaped, bent, twisted, or kiln marked that they will not form a proper surface or align properly with other brick.

All brick which are obviously too soft and too poorly vitrified to endure street wear.

SAND FOR CUSHION.

General.

The sand shall pass a $\frac{1}{4}$ -inch laboratory screen and shall be well graded from coarse to fine. The material removed by the elutriation test, consisting chiefly of clay and loam, shall not exceed 5 per cent by weight.

SAND FOR GROUTING.

The sand shall consist of clean, hard, durable, uncoated stone particles, preferably siliceous, and free from lumps of clay and all organic matter.

It shall be well graded from coarse to fine and, when tested by means of laboratory sieves, shall meet the following requirements:

	Per cent.
Passing 10-mesh sieve-----	100
Passing 20-mesh sieve, not less than-----	80
Passing 100 mesh sieve, not more than-----	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

**Methods of
Testing.**

Tests of the physical properties of the brick and sand shall be made in accordance with the following methods:

1. Rattler Test, A. S. T. M. Standard, C7-15.
2. Grading of Sand, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Elutriation Test for Sand, U. S. Department of Agriculture Bulletin 555, p. 32.
4. Mortar Tensile Strength Test for Sand, A. S. T. M. Standard, C9-17.

SPECIFICATION Br-2.

Vitrified Paving Brick, Cushion Sand, and Grouting Sand for Brick Pavement.

VITRIFIED PAVING BRICK.

All brick shall be of a size commercially known as "3-inch brick." **General.** They shall be thoroughly annealed, tough and durable, regular in size and shape, and evenly burned. When broken, the bricks shall show a dense, stonelike body, free from lime, air pockets, cracks, or marked laminations. Kiln marks shall not exceed $\frac{3}{16}$ of an inch, and the wearing surface shall show but slight kiln marks.

Representative samples of the brick shall meet the following requirements when subjected to the rattler test: **Rattler Test.**

Average loss by abrasion on one or more samples, not more than 26 per cent.

Maximum difference in per cent loss by abrasion when more than one representative sample is tested, not more than 8 per cent, provided, however, that no sample shall show more than 28 per cent loss.

A maximum of three tests will be used as a basis for rejection.

The brick shall meet the following requirements:

	Dimensions.
Length -----	8 to 9
Width -----	3 $\frac{1}{2}$ to 4
Depth -----	2 $\frac{7}{8}$ to 3 $\frac{1}{8}$

Variations among brick from a single plant shall not exceed the following limits:

	Inch.
Variation in length -----	$\frac{1}{2}$
Variation in width -----	$\frac{1}{8}$
Variation in depth -----	$\frac{1}{8}$

Only brick with lugs on one side, raised not less than $\frac{1}{8}$ of an inch and not more than $\frac{1}{4}$ of an inch, shall be used. **Visual Inspection.**

The ends of the brick shall have either a semicircular groove with a radius of not less than $\frac{1}{8}$ of an inch or more than $\frac{1}{4}$ of an inch, or a bulge of at least $\frac{1}{8}$ of an inch.

The name or trade-mark of the manufacturer, if shown on the brick, shall be recessed and not raised.

The bricks shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject upon variations from the general and dimensions clauses and upon the following grounds:

All bricks which are broken through, or chipped in such manner that neither wearing surface remains substantially intact, or in such manner that the lower or bearing surface is reduced in area by more than one-eighth.

All bricks which are cracked to a depth greater than $\frac{1}{8}$ inch on any surface, or which are cracked on the wearing surface.

All bricks which are so offsize or so misshaped, bent, twisted, or kiln marked that they will not form a proper surface or align properly with other bricks.

All bricks which are obviously too soft and too poorly vitrified to endure street wear.

SAND FOR CUSHION.

The sand shall pass a $\frac{1}{4}$ -inch laboratory screen and shall be well graded from coarse to fine. The material removed by the elutriation test, consisting chiefly of clay and loam, shall not exceed 5 per cent by weight. **General.**

SAND FOR GROUTING.

General.

The sand shall consist of clean, hard, durable, uncoated-stone particles, preferably siliceous, free from lumps of clay and all organic matter.

It shall be well graded from coarse to fine and, when tested by means of laboratory screens and sieves, shall meet the following requirements:

	Per cent.
Passing a 10-mesh sieve-----	100
Passing a 20-mesh sieve, not less than-----	80
Passing a 100-mesh sieve, not more than-----	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

When the sand is mixed with Portland cement in the proportion of 1 part of cement to 3 parts of sand by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

Methods of Testing.

Tests of the physical properties of the brick and sand shall be made in accordance with the following methods:

1. Rattler Test, A. S. T. M. Standard, C7-15.
2. Grading of Sand, U. S. Department of Agriculture Bulletin 555, p. 33.
3. Elutriation Test for Sand, U. S. Department of Agriculture Bulletin 555, p. 32.
4. Mortar Tensile Strength Test for Sand, A. S. T. M. Standard C9-17.

These specifications cover vitrified paving brick, cushion sand, and grouting sand for brick wearing course, and sand cushion for two sizes of brick.

The sand cushion or sand cement cushion should preferably be placed upon a concrete foundation to a depth after rolling of not over 1½ inches. This cushion should be shaped to the desired cross section of the finished wearing course before placing the brick. After laying and rolling the brick, the joints are filled with a grout composed of equal parts of cement and grouting sand reduced with water to a creamy consistency. If desired, a bituminous mastic or a bituminous filler may be poured hot into the joints. In the latter case, the requirement for grouting sand and all reference thereto should be eliminated from the specifications.

SPECIFICATION R-1.

Granite Block, Gravel, and Sand for Stone-Block Pavement.

STONE BLOCK.

The stone block shall be of granite of medium-sized grain, showing an even distribution of constituent minerals. They shall be of uniform quality and texture throughout, and free from seams, scales, or disintegrated material.

Sample blocks shall meet the following requirement:		Physical Properties.
French coefficient of wear, not less than-----	8	
Toughness, not less than-----	7	
The blocks shall meet the following requirements:		Dimensions.
	Inches.	
Length on top-----	8 to 12	
Width on top-----	3½ to 4½	
Depth-----	4¼ to 5¼	

The stone block shall be subjected to inspection subsequent to delivery at the place of use, prior to and during laying, in order to cull out and reject those which fail to conform with the general and dimension clauses and the following requirements of this specification:

The blocks shall be so dressed that when laid as specified measurement of any joint shall show a width of not more than ½ inch for a depth of 1 inch, or a width of not more than 1 inch in any part of the joint.

The wearing surface of the blocks shall show no depressions more than ⅜ inch deep, and the edges and corners shall be unchipped and unbroken.

SAND FOR CUSHION.

The sand shall pass a ¼-inch laboratory screen, and shall be well graded from coarse to fine. The material removed by the elutriation test, consisting chiefly of clay and loam, shall not exceed 5 per cent by weight.

SAND FOR GROUTING.

The sand shall consist of clean, hard, durable, uncoated stone particles, preferably siliceous, free from lumps of clay and all organic matter.

It shall be well graded from coarse to fine and, when tested by means of laboratory screens, shall meet the following requirements:

	Per cent.
Passing 10-mesh sieve-----	100
Passing 20-mesh sieve, not less than-----	80
Passing 100-mesh sieve, not more than-----	10

Not more than 5 per cent by weight shall be removed by the elutriation test.

When the sand is mixed with Portland cement in the proportions of 1 part of cement to 3 parts of sand by weight, according to standard methods of making 1:3 mortar briquets, the resulting mortar at the age of 7 and 28 days shall have a tensile strength of at least 75 per cent of that developed in the same time by mortar of the same proportions and consistency, made of the same cement and Ottawa sand.

Preliminary acceptance samples shall be subjected to both 7 and 28 day tests, and acceptance based thereupon. Samples tested during the progress of the work will be accepted on the basis of the 7-day test.

GRAVEL FOR FILLER.

The gravel shall be composed of clean, hard, durable fragments of rock.

When tested by means of laboratory screens it shall meet the following requirements:

	Per cent.
Passing ½-inch screen, not less than-----	95
Retained on ¼-inch, not less than-----	85

Tests of the physical properties of the block, gravel, and sand shall be made in accordance with the following methods:

1. French coefficient of wear, U. S. Department of Agriculture Bulletin 347, p. 4.
2. Toughness, U. S. Department of Agriculture Bulletin 347, p. 15.

3. Grading of gravel and sand, U. S. Department of Agriculture Bulletin 555, p. 33.
 4. Strength test of sand, U. S. Department of Agriculture Bulletin 555, p. 32.
 5. Elutriation test of sand, A. S. T. M. Standard, C9-17.
-

This specification covers granite block, cushion sand, grouting sand, and gravel filler to be used in the construction of a stone-block wearing course and sand cushion.

The requirements for quality of block here given are on the basis of a pavement subjected to comparatively moderate traffic. For very heavy traffic, a French coefficient of wear of 10.0 or 11.0 and a toughness of 9 or 10 may reasonably be required. While a coefficient of hardness of not less than 16 might well be included under physical properties, a requirement for French coefficient of wear has been used instead, owing to the fact that but few laboratories are equipped with a Dorry hardness machine.

The sand cushion, or sand cement cushion, should be placed upon a concrete foundation to a depth of from 1 to 1½ inches and should be carefully shaped to the cross section of the finished pavement at such a height that the blocks after consolidation are at grade. The blocks are usually laid in straight rows at right angles to the curb, with joints broken at least 3 inches, and are rammed to a solid bearing before filling. Joints in block pavements may be filled with either a cement grout, bituminous mastic, or gravel with a poured bituminous filler. Grouting sand as called for in this specification may be used with either Portland cement to form the sand-cement grout, or a bituminous material to form a bituminous mastic. If a gravel and bituminous filler is to be used the requirements for grouting sand and all reference thereto should be eliminated from the specifications.

APPENDIX I.

METHODS OF TESTING.

The following methods of testing are those to which reference is made in the foregoing specifications. In some cases the descriptions from the original references have been condensed, but not changed in any essential particular.

French Coefficient of Wear of Rock or Slag. (Bulletin 347, page 5.)—The determination of the French coefficient of wear is made in an apparatus known as the Deval abrasion machine, shown in figure 1. This machine consists essentially of a number of cast-iron cylinders 20 cm. in diameter and 34 cm. deep inside, which are mounted upon a frame in such a manner that the axes of the cylinders are inclined at an angle of 30 degrees with the axis of revolution of the frame. The following method is essentially the American Society for Testing Materials Standard Test D2-08.

The material to be tested is broken into pieces as nearly of the same size and shape as practicable, so that approximately 50 pieces shall weight, after thorough drying, to within 1 gram of 5,000 grams. In no case should the number of pieces exceed 60 or be less than 40. Care should be taken to use only freshly broken fragments, as pieces with rounded edges greatly affect the results. The pieces may be so broken as to average from 2 to 2½ inches in diameter with the assurance of ordinarily obtaining a properly sized sample. After weighing, the sample is placed in one of the cylinders of the Deval machine, the cover bolted on, and the machine given 10,000 revolutions at the rate of 30 per minute. At the conclusion of the test the sample is screened over a laboratory screen having $\frac{1}{16}$ -inch square openings, the material retained thoroughly washed free from dust, dried in an oven, and again weighed. The difference between this weight and that first obtained represents the wear as determined by test.

The following formula, in which "*a*" represents the final weight of the washed and dried stone, may be used to calculate the French coefficient of wear:

$$\text{French coefficient of wear} = \frac{2000}{5000 - a}$$

Toughness of Rock. (Bulletin 347, page 15.)—The following test for toughness is essentially the same as the American Society for Testing Materials tentative Standard Test D3-17T. It is made on a cylinder 25 mm. long and from 24 to 25 mm. in diameter, cut from the sample of rock to be tested by means of a diamond drill. In cases where any evidences of lamination or foliation exists, two sets of cores are prepared, one set at right angles to and the other set parallel to the foliations. Specimens a little over 25 millimeters long are next cut from the rock cores by means of a diamond saw. The ends are then ground plane on a grinding lap until they are exactly 25 millimeters long. Although it is not necessary that the two ends of the specimens be exactly parallel, one surface of each at least should be as nearly perpendicular

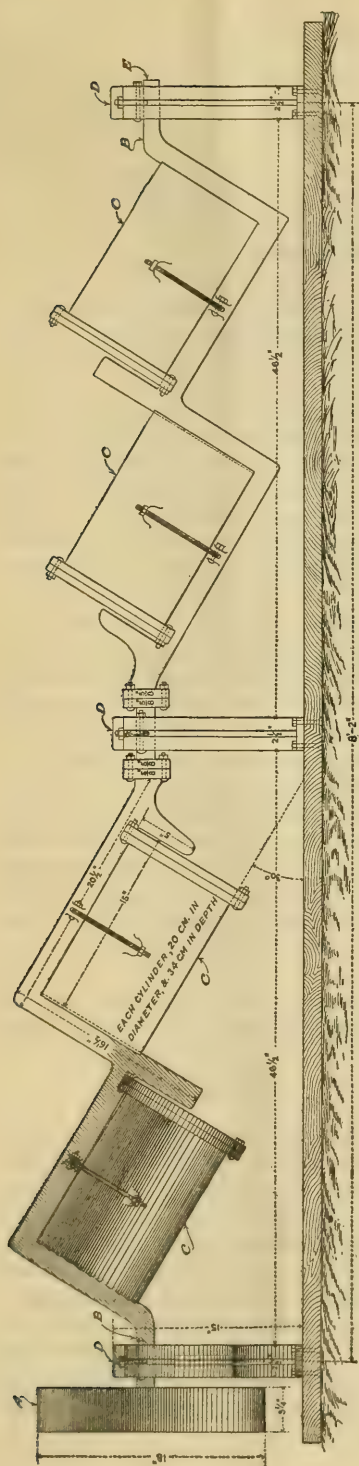


FIG. 1.—Abrasion machine—Deval type (front view).

to the axis of the cylinder as it is possible to make it. After drying and cooling, a specimen to be tested is placed on the anvil (W) of a Page impact machine, shown in figure 2, taking extreme care that when in position the specimen rests with a perfect bearing on the anvil and that the spherical end of the plunger is tangent to the specimen exactly in the center of its upper surface. The small thumbscrew used for separating the clips which hold the specimen in place should be so adjusted that the clips hold the test piece firmly without any undue pressure on the spring. Attention to these details is very important if accurate results are to be obtained. When the specimen is in position the current is turned on the magnet and the upper cross-head is lowered until the rod projecting from it just comes in contact with the rod projecting from the lower cross-head (M). This occurs at the instant the pilot lamp, in series with the magnet circuit, flashes out. The dial (Q) is then adjusted to O, the upper cross-head raised 1 centimeter, and the motor started. After each blow the fall of the hammer is increased 1 centimeter until failure of the test piece occurs.

The height in centimeters of the blow at failure is recorded as the toughness of the material, using for the final value the average of three determinations. In the case of foliated rock the average of three determinations in each direction is taken as the toughness of the sample.

Weight per Cubic Foot of Broken Slag.—The weight per cubic foot should be determined by shaking the dried slag to refusal in a cubic foot cylindrical measure. About $\frac{1}{2}$ of the total amount of slag necessary to fill the measure is first introduced in such a manner as to avoid any separation of sizes. This material is then shaken down by rocking the measure from side to side until no further settlement takes place. This process is repeated until the measure has been filled to overflowing, after which it is struck off level with the top with a straight edge and weighed.

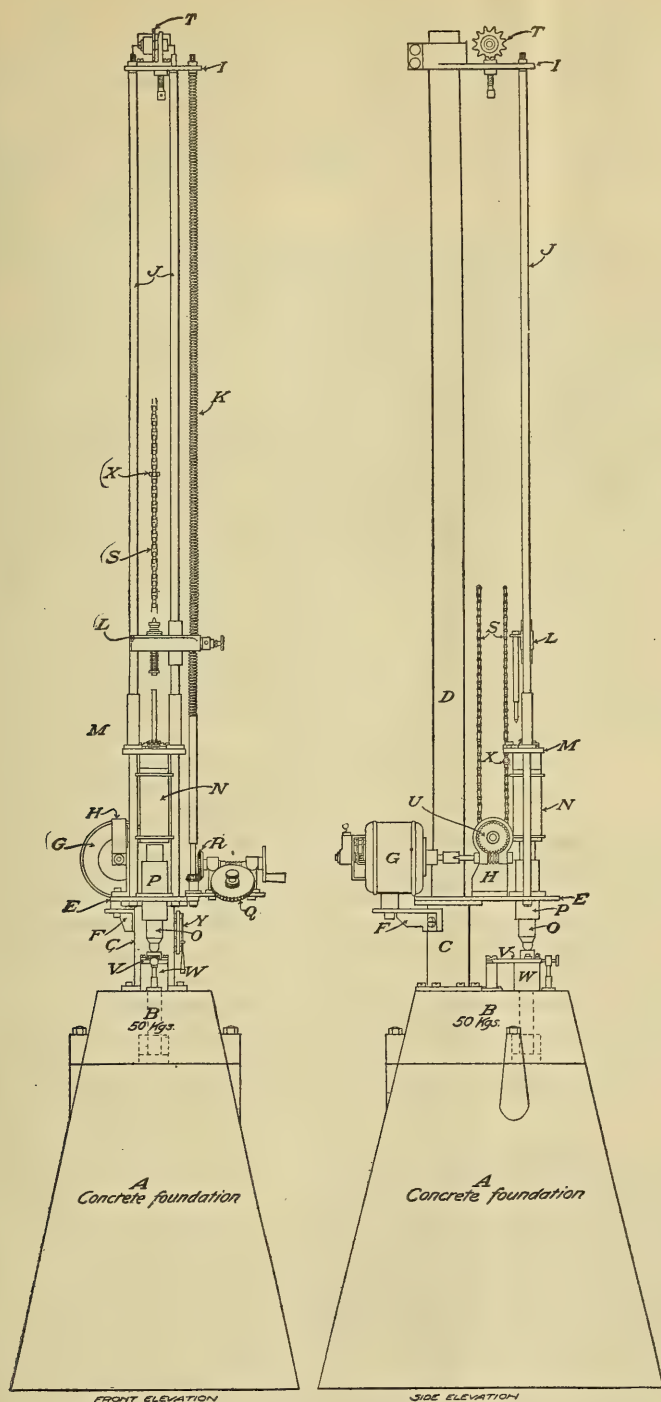


FIG. 2.—Details of Page impact testing machine.

Size, Grading, or Mechanical Analysis of Broken Stone, Broken Slag, or Gravel. (Bulletin 555, page 32 (8).)—A sample of the material weighing not less than fifty (50) times the weight of the largest size stone present is used. After drying at not over 110° C. (230° F.) to constant weight, the sample is passed through such of the following size screens, having circular openings, as are required or called for by the specifications, screens to be used in the order named: 3½-inch, 3-inch, 2½-inch, 2-inch, 1½-inch, 1-inch, ¾-inch, ½-inch, and ¼-inch.

The percentage by weight, retained on each screen, is determined and the mechanical analysis is recorded in the following manner:

	Per cent.
Passing 3½-inch screen and retained on 3-inch screen.....	
Passing 3-inch screen and retained on 2½-inch screen.....	
Passing 2½-inch screen and retained on 2-inch screen.....	
.....	
Passing ½-inch screen and retained on ¼-inch screen.....	
Passing ¼-inch screen.....	

Elutriation Test of Sand. (Bulletin 555, page 32.).—The entire sample is moistened and thoroughly mixed, and a sample weighing approximately 105¹ grams is obtained for elutriation and grading by quartering or by selecting small portions from various parts of a flat pile. The sample is then dried at not over 110° C. (230° F.). This dried sample is accurately weighed and placed in a 500-cc.¹ beaker, and about 350 cc.¹ of water is added and agitated in such manner that no whirling results. After settling for 20 seconds, the water is poured off through a 200-mesh sieve, and the operation of agitation, sedimentation, and decantation repeated until the wash water is approximately clear. Particles caught on the 200-mesh sieve are then washed back into the washed sample remaining in the beaker. The entire washed sample is dried to constant weight and accurately weighed, and the

$$\text{Per cent by elutriation} = \frac{\text{Original weight} - \text{Final weight}}{\text{Original weight}} \times 100.$$

Mechanical Analysis or Grading of Sand or Fine Aggregate. (Bulletin 555, page 33.).—All of the dried sample remaining after the elutriation test, if such is required, is passed successively through the desired screens and sieves, beginning with either the largest or smallest as may be convenient. Where an elutriation test is not required, a dried sample of the original material weighing about 100 grams is used.

The percentage, by weight, of the unwashed sample retained on each screen is determined, and the mechanical analysis is recorded according to one or both of the following methods. A screen with ¼-inch circular openings is used, together with square-mesh sieves as specified in A. S. T. M. Standard Methods D7-16.

	Per cent.
Total retained on ¼-inch screen.....	
Passing ¼-inch screen and retained on 10-mesh sieve.....	
Passing 10-mesh sieve and retained on 20-mesh sieve.....	
Passing 20-mesh sieve and retained on 30-mesh sieve.....	
Passing 30-mesh sieve and retained on 40-mesh sieve.....	
Passing 40-mesh sieve and retained on 50-mesh sieve.....	
Passing 50-mesh sieve and retained on 80-mesh sieve.....	
Passing 80-mesh sieve and retained on 100-mesh sieve.....	
Passing 100-mesh sieve and retained on 200-mesh sieve.....	
Passing 200-mesh sieve.....	
Total.....	100

¹ If the sand is so coarse that a 100-gram sample is not sufficient, the size of the sample, the container, and the amount of water used may be proportionately increased.

Per cent.

Total passing $\frac{1}{2}$ -inch screen.....	
Total passing 10-mesh sieve.....	
Total passing 20-mesh sieve.....	
Total passing 30-mesh sieve.....	
Total passing 40-mesh sieve.....	
Total passing 50-mesh sieve.....	
Total passing 80-mesh sieve.....	
Total passing 100-mesh sieve.....	
Total passing 200-mesh sieve.....	
Passing 200-mesh sieve elutriation.....	

Washing Test and Grading or Mechanical Analysis of Road Gravel. (Bulletin 555, page 32 (9).—A sample of the material weighing not less than 50 times the weight of the largest size stone present is used. After thoroughly drying at 100° C. (212° F.) in a hot-air bath, the sample is cooled, weighed, and placed in a shallow pan, covered with water, and thoroughly agitated by means of a trowel for 15 seconds. After 15 seconds sedimentation the water is poured off through a 200-mesh sieve, and the operation of agitation, sedimentation, and decantation repeated until the wash water is approximately clear after 15 seconds. The washed material, together with any residue retained on the 200-mesh sieve, is then dried to constant weight, cooled and weighed and passed through such of the following size screens and sieves as are called for in the specification, using them in the order named:

Screens (circular openings) : 3-inch, 2 $\frac{1}{2}$ -inch, 2-inch, 1 $\frac{1}{2}$ -inch, 1-inch, $\frac{3}{4}$ -inch, $\frac{1}{2}$ -inch, and $\frac{1}{4}$ -inch.

Sieves, A. S. T. M. Standard Method (square mesh) : 10, 20, 30, 40, 50, 60, 80, 100, and 200 meshes per linear inch.

The percentage by weight retained on each screen or sieve and based on the weight of the original sample is calculated, using for the determination of the percentage of material passing the 200-mesh sieve the sum of the weights of material passing this sieve by analysis and by washing.

Cementing Value of Gravel, Top Soil, or Sand Clay. (Bulletin 347, page 15).—A 500-gram sample of that portion of the material which will pass a $\frac{1}{4}$ -inch screen is placed in a ball mill with 18 per cent water, and the machine given 5,000 revolutions at the rate of 30 per minute. After grinding the resulting dough is removed and molded in a hydraulic briquetting machine into briquettes 25 mm. in diameter and 25 mm. high, under a pressure of 132 kg. per sq. cm. Six briquettes should be made from each sample. They are allowed to dry in the air at ordinary room temperature for 20 hours after making, and are then dried at a temperature of 100° C. for four hours, cooled for 20 minutes in a desiccator, and immediately tested. In making the test the briquette is held in position on the anvil of a Page cementing-value-impact testing machine (fig. 3) by means of a drop of thick shellac, extreme care being taken to see that there is perfect contact between the upper surface of the briquette and the plunger, as well as between its lower surface and the anvil. With the briquette in position, the plunger resting on it, and the cam in the position shown in figure 3, the end of the pin (F) is brought into contact with the surface of the cam and the locknut tightened. This will give an effective drop of 1 cm. to the hammer. The brass pencil is so adjusted that on revolving the drum a horizontal line will be traced on a piece of sensitized paper which has been wrapped around it. On starting the motor, each blow of the hammer will then be recorded in a short vertical line above the base line. The number of blows required to destroy the resilience of the briquette will equal the number of vertical lines showing on the record above the base line. In counting the number of vertical lines showing on the record, no attention should be paid

to the fact that the short horizontal lines gradually drop below the original base line. Each vertical line which shows above the corresponding horizontal base line on its right should be counted as part of the record.

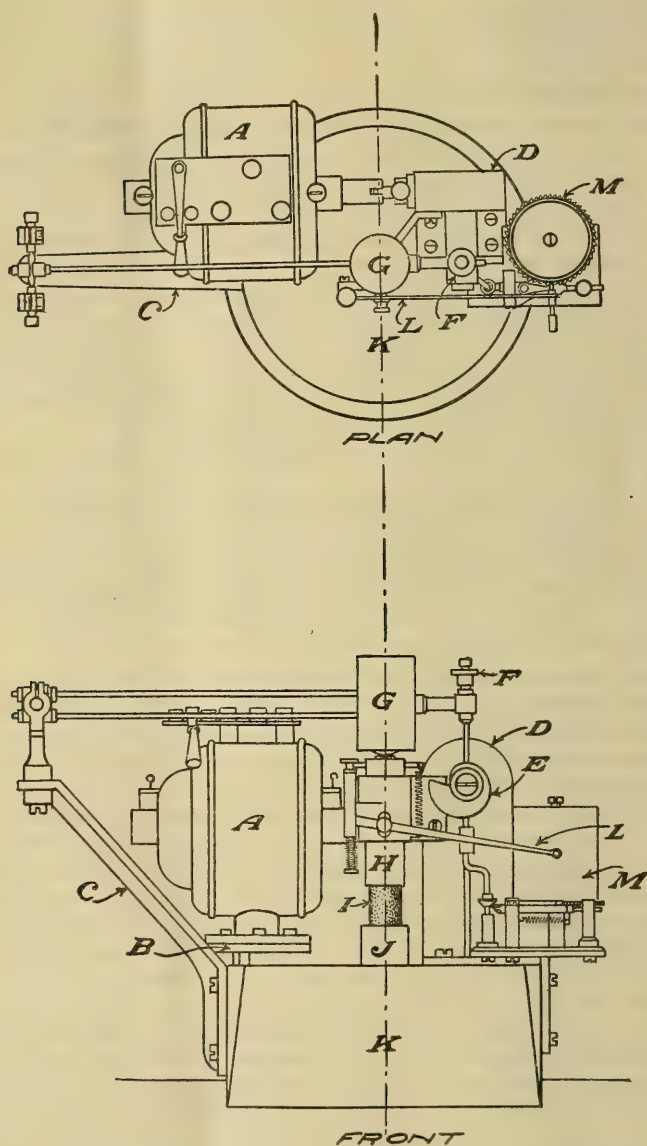


FIG. 3.—Details of Page impact machine for testing cementing value.

The number of blows required to destroy the specimen is called its cementing value. An average of five determinations is taken.

Washing Test and Grading, or Mechanical Analysis of Sand-Clay or Top-Soil. (Bulletin 555, page 35.)—A 500-gram sample of the material is dried at a temperature below 350° F. (176.6° C.) to constant weight, and is gently pulverized to break down soft clods or masses, but not so as to grind or break hard material. The sample is then passed through a 10-mesh sieve, the coarse residue weighed and recorded as “coarse material.” The material passing the 10-mesh sieve is then used as the starting point of a percentage analysis as follows:

Two samples of 50 grams each of this material are weighed out for duplicate analysis. Each is placed in a wide-mouth bottle (5 to 6 cm. diameter and about 12 to 15 cm. high), and about 5 c. c. of dilute ammonia water and about 200 c. c. of water is added. After thoroughly shaking for about 20 minutes, the sample is allowed to settle 8 minutes and the supernatant liquid decanted. The process is repeated until the supernatant liquid is clear. The washings drawn off may be collected and evaporated to dryness for direct recovery of the fine sediment classed as “*clay*.” Ordinarily the sediment loss is computed as difference.

The content of the bottle is washed into a porcelain evaporating dish and carried to dryness on a water bath. The dried residue is then passed through a nest consisting of a 20, 60, 100, and 200 mesh sieve. The residue retained on each sieve is weighed and recorded as *sand* of the respective size. Their sum constitutes the “*total sand*.” The residue passing the 200-mesh sieve and caught in the pan is weighed and recorded as “*silt*.” Duplicate samples should check within 1 per cent.

Tests for Portland Cement. (A. S. T. M. Standard Test C9-17.)—The generally adopted standard methods of testing Portland cement have been so widely circulated through Bureau of Standards Circular No. 33, and publications of the American Society for Testing Materials, that it is thought unnecessary to include them in this bulletin. These tests cover chemical analysis, specific gravity, fineness, soundness, time of setting, and tensile strength.

Mortar Tensile Strength Test for Sand. (Based on A. S. T. M. Standard Test C9-17.)—This test is preferably made with the same brand of cement that will be used in construction, but any Portland cement which meets the standard specifications will serve. Briquets composed of three parts of the sand, which has first been passed through a $\frac{1}{4}$ -inch laboratory screen, to one of cement are made of as near as possible the same consistency as ordinary standard mortar briquets, a set of which should be made at the same time. Such consistency can only be obtained by trial. In general, slightly more water will be required for an ordinary concrete sand than for the standard Ottawa sand. The mortar should be of such consistency after thorough mixing that after squeezing in the hand it will stick together and still retain its shape. If the consistency is other than this, a fresh batch of mortar should be made with more or less water as indicated and the trial repeated until the proper consistency is secured. This is preferable to adding water to a batch of mortar which may have been found to be too dry.

Immediately after mixing, the mortar is placed in the standard molds, pressed in firmly with the thumbs and smoothed off with a trowel without ramming. Additional mortar should be heaped above the mold and smoothed off with a trowel, which should be drawn over the mold in such a manner as to exert a moderate pressure on the material. The mold should then be turned over and the operation of heaping, thumbing, and smoothing off repeated. The briquets must be kept in molds on glass plates in a moist closet for

at least 20 hours. After 24 hours in moist air, the briquets are immersed in clean water in storage tanks of non-corroding material. The air and water should be maintained as nearly as practicable at a temperature of 21° C. (70° F.). The moist closet may consist of a soapstone, slat, or concrete box, or a wooden box lined with metal. If a wooden box is used, the interior should be covered with felt or broad wicking kept wet. The bottom of the moist closet should be covered with water. The interior of the closet should be provided with nonabsorbant shelves on which to place the test pieces, the shelves being so arranged that they may be withdrawn readily. Tests may be made with any standard machine. The briquets are tested as soon as they are removed from the water. The bearing surfaces of the clips and briquets must be carefully centered and the load applied continuously at the rate of 600 pounds per minute. Testing machines should be frequently calibrated in order to determine their accuracy. Briquets that are manifestly faulty, or which give strengths differing more than 15 per cent from the average value of all test pieces made from the same sample and broken at the same period, should not be considered in determining the tensile strength. The average tensile strength in pounds per square inch of not less than three briquets is compared with the average tensile strength of not less than three standard mortar briquets made at the same time and by the same operator with the same cement and Ottawa sand.

Rattler Test for Paving Brick. (A. S. T. M. Standard Test C7-15.)—Following is a brief description of the rattler test. For a detailed description reference should be made to the book of A. S. T. M. Standards, 1916.

The standard rattler test is used for the purpose of determining the resistance to wear of vitrified paving brick. The machine should conform in every respect to the standard requirements covering the construction of the rattler. The abrasive charge consists of 10 cast-iron spheres, weighing when new 7½ pounds each, and a sufficient number of small spheres, weighing when new 0.95 pounds each, to bring the collective total weight of the charge to as nearly 300 pounds as possible. Both small and large spheres should be standardized from time to time, as called for in the detail specification. The brick charge consists of 10 brick, none of which would be rejected on visual inspection. They should be thoroughly dried previous to testing. The test consists of subjecting the brick to 1800 revolutions of the rattler at the rate of not less than 29½ nor more than 30½ revolutions per minute. At the conclusion of the test, the brick are reweighed, rejecting any piece weighing less than 1 pound. The percentage of wear is calculated from the following formula:

$$\text{Per cent wear} = \frac{\text{Original weight} - \text{final weight}}{\text{Original weight}} \times 100.$$

APPENDIX II.

METHODS OF SELECTING AND SHIPPING SAMPLES.

The following directions for selecting and shipping samples of nonbituminous materials should be followed in connection with materials which are to be tested in the laboratory for conformity with the foregoing specifications. It should be noted that most of the tests for size or grading of broken stone, slag, gravel, sand, etc., may and should be made frequently in the field or at the plant with a set of screens or sieves and a rough balance.

General Directions.—(1) Samples should be taken so as to represent as nearly as possible an average of the bulk of material sampled, and in case of principal materials for the higher types of roads, they should also be selected with a view to ascertaining the maximum variation in characteristics which the material may possess. (2) Samples should be packed in such manner as to withstand rough shipment, and special precautions should be taken to prevent the obliteration or removal in transit of tags or identification marks. (3) Notification of shipment of samples, with statement of identification marks and such other descriptive information as may be necessary should be promptly forwarded to the laboratory.

Information Accompanying Samples.—Whenever possible, the following information should be furnished the laboratory in connection with each sample submitted:

- | | |
|---|--|
| 1. Identification mark. | 8. Date sample taken. |
| 2. Name of material. | 9. Place sample taken. |
| 3. Name and address of producer, or owner of deposit. | 10. Sample taken from (quarry, crusher, bin, pit, plant, car, storage pile, or mixer). |
| 4. Location of plant or deposit. | 11. Quantity represented by sample. |
| 5. To be examined for conformity with _____ specification. | 12. Material shipped in car No. ____. |
| 6. Name and location of road where material is to be used. | 13. Date material shipped. |
| 7. Proposed use and type of construction in which material is to be used. | 14. Date material received at destination. |
| | 15. Date used or to be used if satisfactory. |

Time and Plant of Sampling.—(1) Whenever practicable, nonbituminous materials should be sampled at the place of occurrence or manufacture at such time as to allow the test controlling acceptance or rejection to be made in advance of shipment. (2) When impracticable to take samples as above mentioned, they should be taken from the shipment immediately upon delivery. (3) Samples should always be taken when the appearance or quality of the material changes.

BROKEN STONE.

Sampling for Quality.—When tests for physical properties are required, a preliminary sample should be taken from each proposed source of supply at least two weeks before final acceptance. The preliminary sample may, however,

be omitted in cases where material from a well-known source of supply has been tested within one year previous to the date of acceptance or rejection. In such case the report of the last previous test may be used as the basis of acceptance or rejection. Mixed samples may be taken when deemed necessary. Each sample should weigh at least 25 pounds and be composed only of sound interior rock strictly representative of that which it proposed to use. The fragments should be 2 inches in size or larger. In addition, one piece which should measure at least 3 by 4 by 6 inches will be required if a toughness test is to be made. This piece should be free from seams and cracks, and should have the bedding plane marked if practicable. Samples should be shipped in tight boxes or heavy burlap bags.

Sampling for Size or Grading.—Broken stone may be sampled for size at the crusher, from bins, cars, or storage piles on the job. A composite sample composed of samples from different parts of the supply is advisable. Samples should weigh not less than 10 pounds for material containing fragments $\frac{3}{4}$ inch in diameter. Samples of larger aggregates should increase in size up to about 60 pounds, depending upon the diameter and weight of the largest fragments present. When laboratory tests for size are required, samples should be shipped in tight boxes or heavy close canvas bags.

BROKEN SLAG.

Sampling for Quality.—Slag should be sampled from the crusher or that portion of the dump which it is proposed to use, at least two weeks and not more than one month before final acceptance. Additional samples should be taken during progress of the work, whenever the quality or appearance of the slag changes, and at such other times as may be directed. For the French coefficient of wear determination, each sample should weigh at least 25 pounds and be composed of fragments 2 inches in size or larger. Samples of approximately 100 pounds of each size will be needed for determinations of weight per cubic foot, but such test should ordinarily be made at the crusher or on the job. Tight boxes or heavy burlap bags should be used as containers when shipping samples of slag.

Sampling for Size or Grading.—The same directions given under broken stone apply to broken slag.

GRAVEL.

Samples of pit run gravel proposed for use in water-bound gravel road construction should be taken at least 10 days and not more than 6 months prior to the date of acceptance or rejection, and, if from an accepted source of supply, whenever, during the progress of the work, the gravel appears to change markedly in either quality or grading. Great care should always be exercised in sampling a gravel pit to insure obtaining material for test which is strictly representative of that which it is proposed to use. A number of samples may be taken from a single pit if necessary to cover the probable range in grading of the available material. Samples of pit run gravel should weigh from 50 to 75 pounds.

Samples of screened gravel may be taken at the plant, from bins, storage piles, barges, or cars. A composite sample composed of samples from different parts of the supply is advisable in order to determine the average composition of the material. Every shipment of gravel for bituminous concrete or Portland cement concrete should be sampled, in which case no single sample should represent over 100 cubic yards. Samples should weigh from not less

than 10 pounds, for material containing fragments up to $\frac{3}{4}$ -inch in diameter, up to 60 pounds, depending on the size of the largest fragments present.

Shipment of samples should be made in tight boxes or close-woven cloth bags.

SAND.

Before approving a source of supply, samples of sand should be taken at least 10 days prior to the date of acceptance or rejection. Pit samples should be taken only from freshly exposed surfaces, and the number of samples from any given deposit should be sufficient to cover the extreme range in quality of that portion of the deposit which it is proposed to use. Every shipment of sand for bituminous concrete, Portland cement concrete, or grouting should be sampled, and no single composite sample should represent over 100 cubic yards. Additional samples should be taken whenever the appearance of the sand changes. In the case of sand for sheet asphalt, frequent samples should be taken daily at the plant from the drum or bin.

Samples of sand should weigh approximately 10 pounds. They should be shipped in tight boxes, case, or close-woven cloth bags.

MINERAL FILLER.

Each shipment of mineral filler should be sampled. When shipped in bags a composite sample should be prepared from one sample taken from each 20 bags in the shipment. A 1-pound sample may be submitted for examination shipped in a tight box or can.

TOTAL MINERAL AGGREGATES.

When the grading of the total mineral aggregate for bituminous concrete or binder course is specified frequent samples should be taken daily at the plant from the drum or bin. Such samples should weigh approximately 10 pounds and if shipped should be placed in tight boxes or cans.

SAND-CLAY OR TOP SOIL.

Before approving a source of supply samples of natural sand-clay mixtures, top soil, sand, or clay should be taken at least 10 days prior to the date of acceptance or rejection. The number of samples from any given deposit should be sufficient to cover the extreme range in quality of that portion of the deposit which it is proposed to use. Additional samples should be taken whenever the appearance of the material changes. When an artificial mixture is made on the road fragment samples of the finished mix should be taken. Samples should weigh approximately 10 pounds and if shipped should be placed in tight boxes or cans.

PORTLAND CEMENT.

Either individual or composite samples of cement may be submitted. Samples should be taken either at the mill or from cars. Individual samples from cars should represent not more than 50 barrels. If taken from bins, each sample should represent not more than 100 barrels. Composite samples taken from cars should be made up of a sample from 1 sack in each 40 sacks, or 10 barrels combined to form one sample. Composite samples taken at the mill may be either from the conveyor delivering to the bin, in which case one sample of 8 pounds should be taken from each 100 barrels passing over;

from the bins themselves by means of proper sampling tubes, provided samples are taken from points well distributed over the face of the bins; or from the bins at the point of discharge, provided sufficient material is drawn from each discharge to obtain samples representative of the material in the bins. In no case should a single composite sample represent over 200 barrels. Samples should be shipped and stored in air-tight containers. Before testing, they should be passed through a 20-mesh sieve in order to thoroughly mix the sample, break up lumps, and remove foreign material.

PAVING BRICK.

Samples of vitrified paving brick may be taken at the point of manufacture or from cars at the point of delivery. Samples from the plant should preferably be taken from the kiln at the time of emptying. One or more sets of tests, depending upon the size of the kiln, each set consisting of three separate tests, should be made on each kiln. Each test in a set of three should represent approximately a single degree of burning (based on the position of the brick in the kiln), and all 10 of the brick in a single test should be of the same approximate degree of burning. In general, samples selected from piles at the plant should be as nearly as possible representative of the entire run of the brick. Samples from piles should be taken from as many different points corresponding to the length, breadth, and depth of the pile as possible. In no case should they be confined to the upper or outer few layers. Where controversy arises regarding the admissibility of certain types or portions of the lot, entire test samples may be selected from such types or portions having a characteristic appearance in common. When sampled at the point of delivery, a representative sample should be taken from each carload received. Considerations covered under sampling from piles at the plant apply equally to sampling from cars. No bricks should be included in the test lot which would be rejected on the basis of cracks, chips, or other defects covered by the specification clauses for visual inspection. Samples should be shipped in stout boxes or crates in lots of 12, put up in 2 rows of 6 bricks each, separated by a wood partition.

STONE BLOCK.

Stone block may be sampled for quality and size either at the quarry or from cars. A preliminary sample for quality consisting of at least four standard blocks should be submitted from each proposed source of supply at least two weeks prior to the date of acceptance or rejection. Additional samples of blocks may be taken from time to time during the progress of the work, whenever the quality or appearance of the blocks varies, and at such other times as may be directed. No sample should include blocks which would be rejected on visual inspection. Preliminary samples may be omitted in cases where material from the proposed source of supply has been tested within one year prior to the date of acceptance or rejection, in which cases the report of such tests may be used as the basis for acceptance or rejection. Samples of stone blocks should be shipped in stout boxes or crates.

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PROFITABLE MANAGEMENT OF GENERAL FARMS IN THE WILLAMETTE VALLEY, OREGON.

By **BYRON HUNTER** and **S. O. JAYNE**, *Agriculturists.*

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SCOPE OF THE BULLETIN.¹

This bulletin is based on information secured from the analysis of a year's business (1912) on 212 general farms in Marion and Polk Counties, Oreg., and a general farm practice study in the Willamette Valley covering a period of several years. It presents some of the more important factors which influence the profits on the farms studied, shows why the "valley" or silt loam farms are operated more efficiently than the "red hill" or clay farms, and makes recommendations that should materially increase the profitability of general farming throughout the Willamette Valley.

SUMMARY AND CONCLUSIONS.

Of the 212 farms embraced in this study 68 are located on the clay soil and 144 on the silt loam soil.

¹ The figures presented in this bulletin are those secured in a typical year before the war, 1912. It would be impracticable to offer recent figures, because of the unstable conditions prevailing the last few years. The prime emphasis is not to be placed on the presentation of comparative profits for one year, but on the lessons which these figures set forth. In short, it is the desire merely to indicate some of the fundamentals of farming success in the Willamette Valley, drawing upon one typical year for practical illustrations and showing the relationship between the various factors in farming.

Some of the factors which tend to influence efficiency on these farms are: (1) The area of land in summer fallow; (2) the income per productive animal unit; (3) crop yields; and (4) the percentage of the field-crop area devoted to clover and other legumes.

Clover seed was a profitable crop in 1912. During that year over 10 per cent of the total receipts of the silt loam farms were derived from the sale of clover seed, though the crop occupied only 4.5 per cent of the rotation area.

Comparative yields and values of the cereal crops per acre strongly indicate that the area devoted to oats on both the clay and silt loam farms should be reduced, with a view to growing more profitable crops.

The farm income of the clay farms was 4.35 per cent of the capital invested, as compared with 6.64 per cent for the silt loam farms. In other words, the silt loam farms were a half more profitable than the clay farms. The clay farms grow less clover and other legumes than the silt loam farms, had a greater acreage and lower yield of oats, and had a much larger percentage of the rotation area lying idle as summer fallow.

Crop yields may be increased materially on most of the farms studied by devoting more of the tillable land to clover and other legumes. A few of the silt loam farms were probably devoting sufficient area to these crops.

That clover can be grown successfully on the clay farms is shown by the 53 trials, covering over 1,000 acres, on 83.8 per cent of which successful stands were obtained.

AGRICULTURAL HISTORY OF THE VALLEY.

Between 1850 and 1860 most of the prairie lands of the Willamette Valley were brought under cultivation. Even as early as 1844 there was a surplus wheat crop of 10,000 bushels. In the very beginning of the agricultural development of the valley, wheat became the leading crop. Oats were also an important crop, and corn was grown in a limited way. Timothy and cheat¹ were the principal hay crops. Clover was tried superficially and pronounced a failure because the first trials failed to give satisfactory stands. From the most reliable information available it appears that wheat in those early days yielded from 30 to 40 bushels per acre and oats from 50 to 75 bushels.

For a number of years the land produced a crop each year. However, the soil soon became infested with wild oats, and about 1865 the farmers began to summer fallow; that is, the land was clean cultivated once in every three or four years. Under this system of

¹ *Bromus secalinus*.

farming crop yields gradually declined. The average yield of wheat for the Willamette Valley during the early eighties was not far from 17 bushels per acre. The United States Census report shows that the average yield of wheat for Benton, Clackamas, Lane, Linn, Marion, Multnomah, Polk, Washington, and Yamhill Counties for the year 1880 was 14.9 bushels per acre.

The practice of summer fallowing from one-fourth to one-third of the land each year and the production of wheat and oats to the exclusion of almost all other field crops has prevailed on the red hill or clay type of soil to the present time. On the silt loam or "valley" soil, on the other hand, radical changes in the type of farming have taken place. Clover and vetch were introduced during the eighties and early nineties, and the practice of summer fallowing has practically been abandoned on this type of soil. The influence of these leguminous crops on crop yields and the efficient management of these farms will be shown in the tables which follow.

TYPES OF SOIL.

The 212 farms which constitute the basis of this study are located on two distinct types of soil, Salem silt loam and Salem clay.¹ The Salem silt loam is locally known as "valley" or "prairie" soil. It occupies the level and gently rolling valley lands. The soil is a brown to black silt loam, 18 to 24 inches deep. The subsoil is a yellowish to red clay loam which becomes heavier with the depth. The Salem clay type is locally known as "red hill" soil. It occupies a series of rolling hills on either side of the "valley" or silt loam soil. The Salem clay soil consists of 12 to 15 inches of red clay, which is underlain by a clay of much the same color and texture as the surface soil.

DEFINITIONS OF TERMS USED.

Definitions of some of the terms used in this discussion may be found helpful in studying the tables which follow:

Improved land.—The usable portion of the farm. It includes the tillable area and any portion of the farm that has been improved sufficiently to furnish fairly good pasturage.

Rotation area.—That portion of the farm upon which field crops are changed about from year to year. It includes the areas in field crops, summer fallow, and pasture in rotation. It does not include the area in fruit and garden.

Field-crop area.—That portion of the farm occupied by the field crops.

¹ Salem silt loam and Salem clay are terms applied to these soils by the Bureau of Soils, U. S. Department of Agriculture, when making a soil survey in Marion and Polk Counties, 1903.

Crop index.—The yielding power of the soil of a given farm or group of farms expressed as a percentage of the average yielding power of the soil of all farms in the community.¹

Animal unit.—A mature horse or cow, or as many smaller animals as require the feed of a horse or cow, namely, 2 head of young cattle, 2 colts, 5 hogs, 10 pigs, 7 sheep, 14 lambs, 7 goats, 14 kids, or 100 hens.

Productive animal unit.—Includes all animal units except work horses.

Receipts.—The gross income of the farms from all sources.

Expenses.—The total amount necessary to conduct the farm business during the year. It includes, besides all cash outlay, depreciation of equipment and buildings and all unpaid family labor (excepting that of the operator) used in conducting the farm business.

Farm income.—The difference between the gross receipts and the expenses. It is the amount available to the farm family for living, saving, and paying debts after the expenses of conducting the farm business during the year have been paid. It does not include what the farm furnished directly toward the family living.

Percentage farm income is of capital invested.—Farm income does not include the amount the farm furnishes the family in the way of food, fuel, and the use of the farm dwelling. Neither do the expenses include the value of the operator's labor and the cost of his board. These two amounts, that is, what the farm furnished the family and the value of the operator's labor and the cost of his board, were so nearly equal on the farms studied that percentage farm income is of capital invested is used in this discussion to measure the efficiency of farming.

¹ The crop index may be defined as the crop yields of a particular farm expressed in percentage of the average crop yields of all the farms in the community. It is found as in the following example:

A particular farm produces—

2,000 bushels of corn on	40 acres,
1,200 bushels of wheat on	40 acres,
900 bushels of oats on	30 acres, and
120 tons of hay on	80 acres.
Total.....	190

The average yields of the above crops in the community are: Corn, 60 bushels; wheat, 32 bushels; oats, 40 bushels; and hay, 1½ tons per acre. Hence, on the average, the areas required to produce the above quantities of the products mentioned are—

2,000÷60=	33.3 acres of corn,
1,200÷32=	37.5 acres of wheat,
900÷40=	22.5 acres of oats, and
120÷1½=	68.6 acres of hay.
Total=	161.9

Thus, it requires 190 acres on the farm in question to produce what 161.9 acres produces on the average. Hence, 1 acre produces on this farm $161.9 \div 190$, or 85.3 per cent as much as the average acre of the community.

USE AND VALUE OF LAND.

The comparative size of farm, value of real estate per acre, and the use made of the farm area on the two types of soil are shown in Table I.

TABLE I.—*Relation of type of soil to use and value of land on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Use and value of land.	Salem clay.	Salem silt loam.
Number of farms.....	68	144
Average size of farm (acres).....	260	175
Value of real estate per acre.....	\$89	\$112
Percentage of farm area in—		
Improved land.....	71.2	73.6
Tillable land.....	67.9	70.9
Rotation.....	63.7	65.3
Field crops.....	46.7	62.2
Pasture.....	26.7	27.8
Summer fallow.....	15.6	1.8
Fruit and garden.....	1.5	1.0
Woodland.....	24.9	22.7
Waste land.....	3.9	3.7

It will be seen that the 68 clay farms averaged 85 acres larger and had a real-estate value \$23 per acre less than the silt loam farms. There was 2.4 per cent more of the farm area in improved or usable land and 13.8 per cent less of the farm area lying idle as summer fallow on the silt loam farms than on the clay farms. The relation of these differences to the comparative efficiency of farming on the two types of soil will be indicated elsewhere.

USE OF CAPITAL.

The average investment and the use made of capital on the 212 farms are shown in Table II. The clay farms had an average of \$3,873 more capital than the silt loam farms, and the silt loam farms had 0.6 per cent more of the total capital invested in working capital than the clay farms.

TABLE II.—*Use of capital on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Use of capital.	Salem clay.	Salem silt loam.
Number of farms.....	68	144
Investment per farm.....	\$25,330	\$21,457
Percentage of investment on—		
Real estate.....	91.6	91.0
Implements and machinery.....	1.9	2.2
Live stock.....	5.9	6.2
Feed and supplies.....	.1	.1
Cash to run farm.....	.6	.5
Working capital.....	8.4	9.0

TYPES OF FARMING.

The number of farm records obtained in the survey made in Marion and Polk Counties in 1912 is not sufficient to justify comparisons of the many types of farming to be found in the Willamette Valley. For this reason all of the records of the survey except 212, those representing general or mixed farming, were discarded. The types of farming practiced on these 212 farms will be considered from the standpoint of the use made of the rotation area, the live stock kept, and the sources of income.

RELATION OF THE ROTATION AREA TO TYPE OF FARMING.

Figure 1 represents graphically the use made of the rotation area on the two types of soil. Oats, it will be seen, were the most promi-

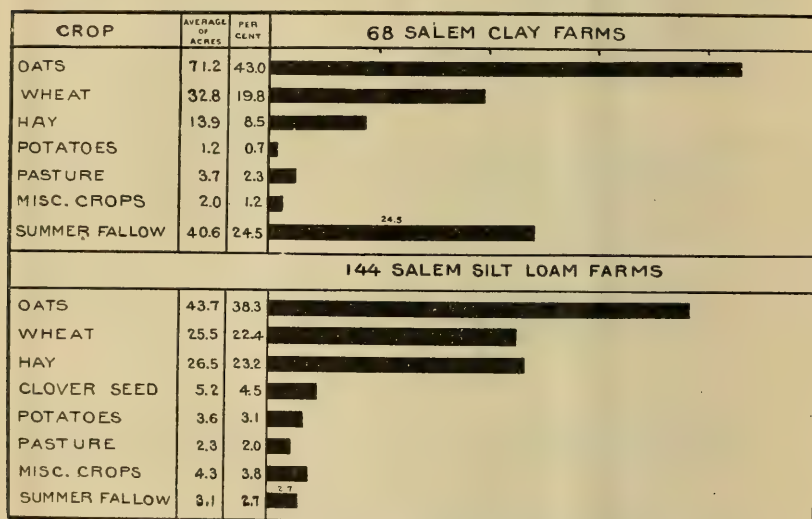


FIG. 1.—Utilization of rotation area on 212 farms in Marion and Polk Counties, Oreg. (1912).

nent crop grown, and oats and wheat occupy relatively about the same percentage of the rotation area on the clay farms as on the silt loam farms. The types of farming followed on the two soils differ materially in the percentage of the rotation area devoted to clover seed, hay, and summer fallow. The prominence of the oat crop and the difference in the uses made of the rotation, it will be seen later, have considerable influence on the comparative profitability of farming on the two soils.

RELATION OF LIVE STOCK TO TYPE OF FARMING.

Figure 2 shows the number of animal units kept per 100 acres of improved land, and the number of animals of each kind kept per farm. It will be seen that dairy cows were the most important

productive animals kept on these farms. Work horses, it must be remembered, are not considered productive animals. Sheep stood second in importance on the clay farms, and hogs on the silt loam farms. The clay farms kept relatively less stock than the silt loam

KIND OF ANIMAL	68 SALEM CLAY FARMS		144 SALEM SILT LOAM FARMS	
	ANIMALS PER FARM	ANIMAL UNITS	ANIMALS PER FARM	ANIMAL UNITS
DAIRY COWS	4.2	2.28	4.6	3.59
BULLS	.2	.11	.3	0.21
YOUNG CATTLE	2.8	.75	2.8	.113
STEERS	.4	.20	(a)	.04
HORSES	5.1	2.71	4.7	3.52
COLTS	1.6	.44	1.4	.64
GOATS	2.0	.15	3.0	.32
SHEEP	25.6	1.56	12.5	1.15
HOGS	11.5	.99	17.1	2.18
POULTRY	134.1	.71	132.4	1.03

FIG. 2.—Number of animal units per 100 acres of improved land and number of animals per farm on 212 farms in Marion and Polk Counties, Oreg. (1912).

farms. The total animal units kept per 100 acres of improved land on the clay farms were 10.02, as compared with 13.77 on the silt loam farms. These are very low complements of live stock. In other words, live stock on these farms was kept as a side line to cash-crop farming.

SOURCE OF INCOME	68 SALEM CLAY FARMS		144 SALEM SILT LOAM FARMS	
	AVERAGE RECEIPTS	PERCENTAGE OF RECEIPTS	AVERAGE RECEIPTS	PERCENTAGE OF RECEIPTS
OATS	569	27.8	393	17.2
WHEAT	482	23.6	296	12.9
POTATOES	70	3.4	168	7.4
HAY	38	1.9	173	7.6
FRUIT	15	.7	23	1.0
CLOVER SEED		.0	231	10.1
MISC. CROPS	14	0.6	44	2.0
DAIRY CATTLE	234	11.5	327	14.3
HORSES	168	8.3	96	4.2
POULTRY	129	6.3	130	5.7
SHEEP	103	5.0	53	2.3
HOGS	93	4.5	156	6.8
STEERS	8	0.4	2	0.1
GOATS	5	0.2	4	0.1
INCREASE FEED AND SUPPLIES	37	1.8	81	3.5
MISC. RECEIPTS	78	3.8	109	4.8

FIG. 3.—Percentage of receipts and amounts received from different sources on 212 farms in Marion and Polk Counties, Oreg. (1912).

RELATION OF SOURCES OF INCOME TO TYPE OF FARMING.

The percentage of receipts from different sources for the two types of soil are shown in figure 3. The clay farms received 58.2 per cent of their receipts from the sale of crops, and the silt loam farms 58.1 per cent. The clay farms, it will be observed, received practically

all of their crop receipts from the sale of oats and wheat. While oats and wheat lead on the silt loam farms also, 10.1 per cent of the total receipts were from clover seed, 7.6 per cent from hay, and 7.4 per cent from potatoes. It will thus be seen that the silt loam farms had receipts from a much greater variety of crops.

The total percentage of receipts derived from all kinds of live stock was 36.2 on the clay farms, and 33.6 on silt loam farms. Obviously these farms were not dealing extensively in live stock. As a source of direct income the dairy cow was the most important animal kept on both kinds of soil. On the clay farms horses stood second, poultry third, sheep fourth, and hogs fifth. On the silt loam farms hogs were second, poultry third, horses fourth, and sheep fifth.

CLAY AND SILT LOAM TYPES OF FARMING CONTRASTED.

It will be seen, therefore, that the type of farming practiced on the 68 clay farms during the year 1912 was that of grain farming under a system of summer fallowing approximately one-fourth of the rotation area each year. Oats occupied more than twice as much land as wheat, and oats, wheat, and summer fallow occupied 87.3 per cent of the rotation area. General live stock were kept as a side line, dairy cows being the most important productive animals.

The type of farming practiced on the 144 silt loam farms was more general and diversified than that practiced on the clay farms. While oats and wheat were still the leading crops, hay and potatoes were given much more prominence. Clover-seed production was also a very important minor farm enterprise, and only 2.7 per cent of the rotation area lay idle as summer fallow, as compared with 24.5 per cent on the clay farms. General live-stock production was also carried as a side line, and dairy cows were slightly more prominent than on the clay farms.

SOME FACTORS WHICH INFLUENCE EFFICIENCY.

Many factors influence efficiency on general farms in the Willamette Valley. Some of these are of minor importance and make little difference in the financial results. Others are very important and largely determine success or failure on most farms. In discussing this topic only those factors are considered which are largely within the control of the farmer and which stand out prominently as contributing to the profit or loss of these farms.

SUMMER FALLOW.

From 40 to 50 years ago the practice of summer fallowing the land once every three or four years was universally followed in the Willamette Valley. While the practice still prevails on the clay farms, it has practically disappeared on the silt loam farms.

TABLE III.—*Relation of summer fallow to percentage farm income is of capital on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Item.	Rotation area in summer fallow.				
	On Salem clay.			On Salem silt loam.	
	None.	25 per cent or less.	Over 25 per cent.	None.	50 per cent or less.
Number of farms.....	11	29	28	127	17
Average percentage of rotation area in summer fallow.....	0	17.6	33.9	0	18.8
Average capital.....	\$11,783	\$27,030	\$28,891	\$20,936	\$25,532
Average farm income.....	\$687	\$1,375	\$985	\$1,471	\$1,081
Percentage farm income is of capital.....	5.83	5.09	3.41	7.02	4.23

In Table III the farms are divided according to the percentage of the rotation area that was in summer fallow. Of the 68 clay farms, 11 had no summer fallow, 29 had 25 per cent or less, and 28 had over 25 per cent of the rotation area in summer fallow. Of the 144 silt loam farms, 127 had no summer fallow and 17 had more or less summer fallow. Using as a measure the percentage farm income is of the capital, it will be seen that the groups of farms having no summer fallow were operated most efficiently. By dividing 5.83 by 3.41 it will be seen that the clay farms having no summer fallow were 1.71 times as efficient as those having over 25 per cent of the rotation area in summer fallow. Likewise the silt loam farms having no summer fallow were 1.66 times as efficient as the farms having summer fallow. Hence, efficiency on these farms may be increased by adopting cropping systems and rotations which will decrease the acreage in summer fallow.

INCOME PER PRODUCTIVE ANIMAL UNIT.

Where crops are grown and fed to live stock on the farm, few factors have as great an influence as income per productive animal unit. Although a farm produces excellent crops, it may still be low in efficiency if the crops produced are fed to live stock of inferior quality or if poor judgment is used in marketing live stock and live-stock products.

TABLE IV.—*Relation of income per productive animal unit to percentage farm income is of capital on 212 farms in Marion and Polk Counties, Oreg. (1912).*

[Farms on the two types of soil divided into three groups, according to income per productive animal unit.]

Item.	Income per productive animal unit.					
	On Salem clay.			On Salem silt loam.		
	Less than \$44.	\$44 to \$62.	Over \$62.	Less than \$44.	\$44 to \$62.	Over \$62.
Number of farms.....	26	20	22	47	47	50
Average income per productive animal unit.....	\$29	\$50	\$77	\$29	\$53	\$82
Average capital.....	\$25,739	\$27,841	\$22,564	\$21,090	\$20,118	\$23,060
Average farm income.....	\$738	\$1,154	\$1,488	\$931	\$1,248	\$2,056
Percentage farm income is of capital.....	2.87	4.15	6.60	4.41	6.21	8.92
Crop index.....	96	102	102	89	106	110

From Table IV it will be seen that farm income was 6.6 per cent of the capital invested in the group of clay farms having an income of \$77 per productive animal unit as compared with 2.87 per cent in the group of farms having but \$29 income per productive animal unit. Likewise the group of silt loam farms having an average income of \$82 per productive animal unit made 8.92 per cent as compared with 4.41 per cent for the group having but \$29 income per productive animal unit. Evidently, farm efficiency on both the clay and silt loam soils was greater where the income per productive animal unit was greater.

Securing a high income per productive animal unit in the main involves (1) the use of farm animals as scavengers to consume all feed that would otherwise go to waste; (2) economical and efficient feeding; (3) the breeding up of animals which will sell well and use feed economically; and (4) the use of good business judgment in marketing.

The variation in the percentage farm income is of capital in the different groups of farms in Table IV was partly due to a variation in crop yields, for it will be seen that the groups of farms having the highest income per productive animal unit also had the highest crop index. Especially is this true with the groups of silt loam farms where the crop index varies from 89 in the group of farms receiving \$29 per productive animal unit to 110 in the group receiving \$82 per productive animal unit. On the clay soil the influence of crop yields was not so prominent, since the variation in crop index only ranged from 96 in the group of farms receiving \$29 per productive animal unit to 102 in the group receiving \$77 per productive animal unit.

CROP YIELDS.

In Table V the farms are divided into groups according to crop index. The crop index of the clay farms is based entirely upon the 68 clay farm records. Likewise, the crop index of the silt loam farms is based only upon the 144 silt loam farm records.

TABLE V.—*Relation of crop yields to percentage farm income is of capital on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Item.	Salem clay.			Silt loam.		
	Crop index 91 and less.	Crop index 92 to 106.	Crop index 107 and over.	Crop index 89 and less.	Crop index 90 to 109.	Crop index 110 and over.
Number of farms.....	23	23	22	43	50	51
Average crop index.....	79	99	118	76	101	124
Income per productive animal unit.....	\$40	\$55	\$59	\$43	\$55	\$66
Capital (average).....	\$24,764	\$22,021	\$28,472	\$21,630	\$21,798	\$20,975
Farm income (average).....	\$653	\$1,085	\$1,596	\$746	\$1,485	\$1,940
Percentage farm income is of capital.....	2.64	4.93	5.61	3.44	6.81	9.25

The crop indexes of the three groups of clay farms were 79, 99, and 118. The percentage that farm income was of the capital for these three groups of farms was 2.64, 4.93, and 5.61, respectively. It will be observed that the percentage for the group of 22 farms with an average crop index of 118 was 2.12 times as great as that for the group of 23 farms whose crop index averaged 79. The influence of crop yield on efficiency was even more pronounced on the silt loam farms. The crop indexes of the three groups of silt loam farms were 76, 101, and 124, while the percentage that farm income was of capital for these three groups was 3.44, 6.81, and 9.25, respectively. In other words, the group of 51 farms with an average crop index of 124 was 2.69 times as efficient as the group of 43 farms with an average crop index of 76.

The difference in the percentage farm income is of capital in the different groups of farms in Table V is the result of the combined influence of crop yield and income per animal unit; for, as the table shows, those farmers whose yields were highest also obtained, on the average, the highest income per animal unit. Tabulations not given here show that of the difference between the farm incomes of the lowest and those of the highest groups, from \$250 to \$300 is due to difference in income per animal unit. Most of the remainder is due to difference in yield.

PERCENTAGE OF FIELD-CROP AREA IN LEGUMES.

The field-crop area is that portion of the farm upon which crops were grown during 1912, the year the farm survey was made. During that year a very limited area was devoted to leguminous crops on the clay farms. For that reason Tables VI, VII, and VIII deal only with the 144 silt-loam farms. In Table VI the farms are divided according to the percentage of the field-crop area in legumes—i. e., in clover, alfalfa, peas, and beans.

TABLE VI.—*Relation of percentage of field-crop area in legumes to percentage farm income is of capital on 144 silt loam farms in Marion and Polk Counties, Oreg. (1912).*

Item.	Per cent of field crop area in legumes—			
	None.	Under 18.	18 to 33.	Over 33.
Number of farms.....	35	37	37	35
Average percentage of field-crop area in legumes.....		12.0	26.0	44.8
Average improved land (acres).....	112	133	139	121
Average capital.....	\$19,821	\$23,368	\$23,272	\$19,181
Average farm income.....	\$770	\$1,425	\$1,834	\$1,648
Percentage farm income is of capital.....	3.89	6.10	7.88	8.60

Of the 144 farms in Table VI, 35 grew no legumes. There were 37 farms with an average of 12 per cent, 31 with an average of 26 per cent, and 35 with an average of 44.8 per cent of the field-crop area in legumes. The percentage farm income is of capital for these groups of farms was 3.89, 6.10, 7.88, and 8.60, respectively. It will be seen

that the group of farms having an average of 44.8 per cent of the field-crop area in legumes was operated 2.21 times as efficiently as the group of farms that grew no legumes.

PERCENTAGE OF FIELD-CROP AREA IN CLOVER.

Table VI shows the influence of all legumes collectively on the returns of the silt-loam farms. Table VII is confined to a single legume—clover. Of the legumes grown on these farms, clover is by far the most important, with vetch occupying second place.

TABLE VII.—*Relation of percentage of field-crop area in clover to percentage farm income is of capital on 144 silt loam farms in Marion and Polk Counties, Oreg. (1912).*

Item.	All farms.	None.	Per cent of field-crop area in clover—	
			Less than 20.	20 or more.
Number of farms.....	144	61	45	38
Average per cent of field-crop area in clover.....	12.0	.....	11.1	32.7
Average capital.....	\$21,457	\$20,228	\$23,192	\$21,372
Average farm income.....	\$1,425	\$1,026	\$1,614	\$1,843
Percentage farm income is of capital.....	6.64	5.06	6.96	8.63

The importance of the clover crop is shown in Table VII. Of the 144 farms, 61 grew no clover in 1912. Forty-five farms had an average of 11.1 per cent, and 38 farms had an average of 32.7 per cent of the field-crop area in clover. The average farm incomes of these three groups of farms were 5.06, 6.96, and 8.63 per cent, respectively, of the capital invested. The 38 farms having an average of 32.7 per cent of the field-crop area in clover were 1.71 times as efficient as those having no clover.

CLOVER-SEED PRODUCTION.

Table VIII shows that clover seed was a very profitable crop in the Willamette Valley in 1912. The average yield per acre on the 54 farms that produced clover seed was 286 pounds for the first crop and 108 pounds for the second crop. The average price received for clover seed was 14.67 cents. The yields and prices are averages for both red and alsike clover for the year 1912.

TABLE VIII.—*Relation of clover-seed production to percentage farm income is of capital on 144 silt loam farms in Marion and Polk Counties, Oreg. (1912).*

Item.	None.	Per cent of receipts from clover seed—	
		Less than 14.	14 or more.
Number of farms.....	90	28	26
Average percentage of receipts from clover seed.....	.....	6.8	32.4
Average capital.....	\$19,900	\$21,971	\$26,291
Average farm income.....	\$1,075	\$1,709	\$2,332
Percentage farm income is of capital.....	5.40	7.78	8.87

There were 90 farms on which no clover seed was sold. On 28 farms 6.8 per cent, and on 26 farms 32.4 per cent, of the receipts were from the sale of clover seed. The average farm incomes of these three groups were, respectively, 5.40, 7.78, and 8.87 of the capital invested. Thus 26 farms which received an average of 32.4 per cent of their receipts from the sale of clover seed were 1.64 times as efficient as the 90 farms that sold no clover seed.

CHOICE OF CEREAL CROPS.

Table IX shows the comparative value and yield of oats, wheat, barley, and corn per acre in the Willamette Valley. The yields per acre are averages computed from the United States Census Reports for the years 1880, 1890, 1899, and 1909. The values per acre are based upon the average prices of these crops at Portland, Oreg., for the 10-year period, 1906 to 1915, inclusive. The price of barley is used in computing the value of corn, it being assumed that these two crops are approximately equal in value, pound for pound.

TABLE IX.—*Comparative value and yield of oats, wheat, barley, and corn per acre for the nine counties of the Willamette Valley, Oreg. (U. S. Census Reports 1880, 1890, 1899, 1909).*

Yield and value per acre.	Oats.	Wheat.	Barley.	Corn.
Yield per acre:				
Bushels.....	28.5	18.9	26.8	26.9
Pounds.....	912	1,134	1,286	1,506
Value per acre.....	\$12.14	\$16.53	\$16.15	\$18.92

From the standpoint of value as stock feed, 912 pounds of oats are not to be compared with 1,134 pounds of wheat, 1,286 pounds of barley, or 1,506 pounds of corn. It will also be seen that there is a marked difference in the cash value of these crops, oats being worth \$12.14, wheat \$16.53, barley \$16.15, and corn \$18.92 per acre.

TABLE X.—*Comparative value and yield of oats, wheat, and barley per acre on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Yield and value per acre.	Salem clay (68 farms).		Salem silt loam (144 farms).		
	Oats.	Wheat.	Oats.	Wheat.	Barley.
Yield per acre:					
Bushels.....	30.8	25.2	37.7	22.0	36.6
Pounds.....	986	1,512	1,206	1,320	1,757
Value per acre.....	\$13.12	\$22.02	\$16.05	\$19.23	\$22.06

Table X shows the comparative value and yield per acre of oats and wheat on the 68 clay farms, and of oats, wheat, and barley on the 144 silt loam farms for the year 1912. The values per acre in this table are also based on the average prices at Portland, Oreg., for 10 years. Of the 68 clay farms, only one reported barley, and barley is therefore not considered under the clay type of soil.

It will be seen that the average yield of wheat on the clay farms was 526 pounds per acre greater than the yield of oats; also that the wheat crop was worth \$8.90 per acre more than the oat crop. Differently stated, the wheat crop was worth 1.68 times as much per acre as the oat crop. On the silt loam farms, according to Table X, the yield of oats per acre was 114 pounds and 551 pounds, respectively, below the yield of wheat and barley. Likewise, the cash value of the oat crop per acre was \$3.18 and \$6.01, respectively, below the value of the wheat and barley crops.

If Tables IX and X represent even approximately the comparative values and yields per acre of oats, wheat, barley, and corn, the profitability of general farming in the Willamette Valley may be increased greatly by a readjustment of the acreage devoted to these crops. Since oats occupied 43 per cent and wheat but 19.8 per cent of the rotation area on the clay farms, it would appear from a study of Table X that oats should largely be replaced by wheat or some other more profitable crop. It should be remembered, however, that most of the wheat crop of the clay farms was grown upon land that had been summer fallowed the previous year, while little or none of the oat crop was grown on summer-fallowed land.

On the silt loam farms studied in 1912 oats occupied 38.8 per cent of the rotation area. This was nearly twice the area occupied by any other crop. A study of Tables IX and X seems to indicate also that much of the oat crop on the silt loam farms can be replaced profitably by other crops. While Table IX shows that corn is the most profitable of the cereal crops, the moist fall and winter climatic conditions of the Willamette Valley practically limit its production to what can be used on the farm. Owing to its superior yield corn should be grown much more extensively, especially for silage and fall and early winter feeding. It will be claimed by some that much of the oat crop is produced on land that will not raise good barley. While there may be some merit to this claim, most Willamette Valley soils produce good yields of barley. Since barley is the equal of oats, pound for pound, as a general stock feed, and since our present knowledge indicates that there is a marked difference in the yield of the two crops, it appears that the acreage of oats should be cut down and that barley should be grown more extensively.

SOME FACTORS WHICH INFLUENCE CROP YIELDS.

Table V shows that the percentage farm income of capital was highest in the group of farms having the highest average crop yields. Any means whereby crop yields may be increased, therefore, should be highly important. The following discussion deals with a few of the more practical ways of increasing crop yields.

RELATION OF LEGUMINOUS CROPS TO CROP YIELDS.

Table VI shows that the group of silt loam farms having the greatest percentage of the field crop area in legumes was operated most efficiently. Apparently, therefore, the legumes were profitable crops. Aside from being profitable crops themselves, legumes also affect the yields of other crops. Table XI shows the influence of leguminous crops on the yields of potatoes, wheat, oats, and hay on the 144 silt loam farms in 1912.

TABLE XI.—*Relation of percentage of field-crop area in legumes to crop yields on 144 farms on silt loam soil, Marion and Polk Counties, Oreg. (1912).*

Item.	All farms.	No legumes.	Per cent of field crop area in legumes.		
			Under 18.	18 to 33.	Over 33.
Number of farms.....	144	35	37	37	35
Average percentage of field-crop area in legumes.....	20.4	.....	12.0	26.0	44.8
Crop yields per acre:					
Potatoes (bushels).....	150.2	132.8	145.5	172.0	183.5
Wheat (bushels).....	22.0	18.8	21.5	23.8	23.7
Oats (bushels).....	37.7	28.5	38.3	40.9	44.5
Hay (tons).....	1.94	1.82	2.00	1.86	2.07
Crop index.....	100	83	100	105	111

There were 35 farms that grew no legumes, 37 that had an average of 12 per cent, 37 that had an average of 26 per cent, and 35 that had an average of 44.8 per cent of the field-crop area in leguminous crops. The yields of potatoes and oats increased steadily, though not in the same ratio, as the percentage of the field-crop area in legumes increased; the yield of wheat of each of the three groups of farms growing legumes was considerably higher than that of the 35 farms having no legumes; and the groups of farms growing legumes had slightly higher yields of hay than did the group having no legumes. Crop index, it will be observed, varied from 83 for the group of farms having no legumes to 111 for the group having an average of 44.8 per cent of the field-crop area in legumes.

Figure 4 is a graphical representation of the percentage of increase in the yields of potatoes, wheat, and oats for the three groups of farms of Table XI which grew legumes, as compared with the yields of these crops for the group of farms having no legumes. It will be seen that the percentage of increase in the yields of potatoes and oats advanced steadily from group to group, although not proportionally, as the percentage of field-crop area in legumes increased; and that the percentage of increase in the yield of wheat advanced in the two groups of farms having an average of 12 and 26 per cent of the field-crop area in legumes and then declined one-half per cent in the next group. The yields of wheat, potatoes, and oats for the group of farms having an average of 44.8 per cent of the field-crop area in legumes were 26, 38, and 56 per cent greater, respectively, than the yields of these crops for the group of farms that grew no legumes.

RELATION OF CLOVER TO CROP YIELDS.

Of the leguminous crops grown on the silt loam farms, clover was by far the most important, with vetch second. In Table XII the farms are arranged in groups according to the percentage of the field-crop area devoted to clover.

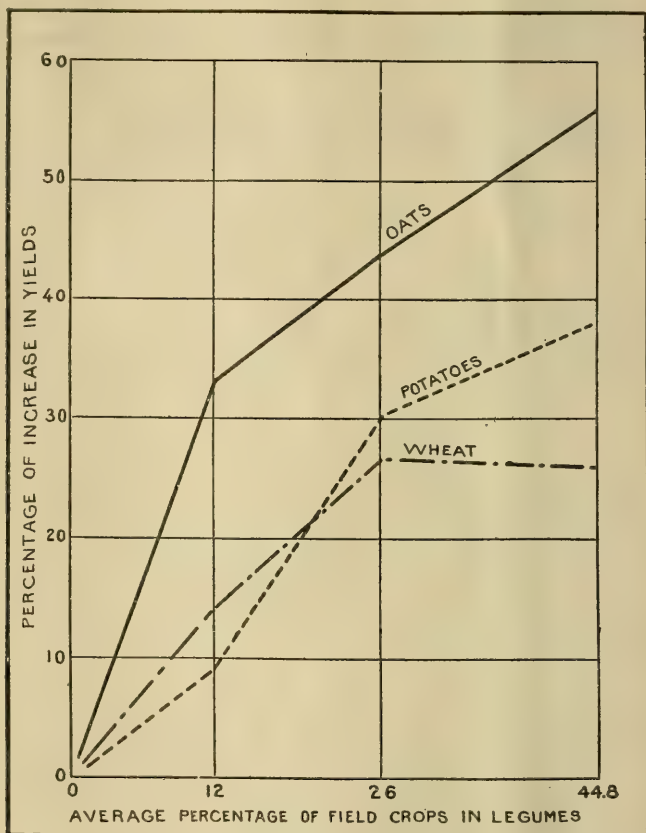


FIG. 4.—Percentage of increase in crop yields with increase in percentage of field crop area in legumes on 144 silt loam farms in Marion and Polk Counties, Oreg. (1912).

TABLE XII.—Relation of percentage of field-crop area in clover to crop yields on 144 silt loam soil farms, Marion and Polk Counties, Oreg. (1912).

Item.	All farms.	Per cent of field-crop area in clover.		
		No clover.	Less than 20.	20 or more.
Number of farms.....	144	61	45	38
Average per cent of field-crop area in clover.....	12.0	.....	11.1	32.7
Crop yields per acre:				
Potatoes (bushels).....	150.2	140.4	159.0	163.7
Wheat (bushels).....	22.0	20.5	22.1	24.9
Oats (bushels).....	37.7	34.1	38.2	45.5
Hay (tons).....	1.94	1.82	2.00	2.05
Crop index.....	100	92	102	113

On 61 farms no clover was grown; 45 farms devoted less than 20 per cent and 38 farms over 20 per cent of the field-crop area to clover. It will be observed from this table that the yields of potatoes, wheat, and oats steadily increased when the percentage of the field-crop area in clover increased. The yield of hay, also, was approximately one-fourth of a ton per acre greater on farms growing clover than on those having no clover. The crop index ranged from 92 for the group of

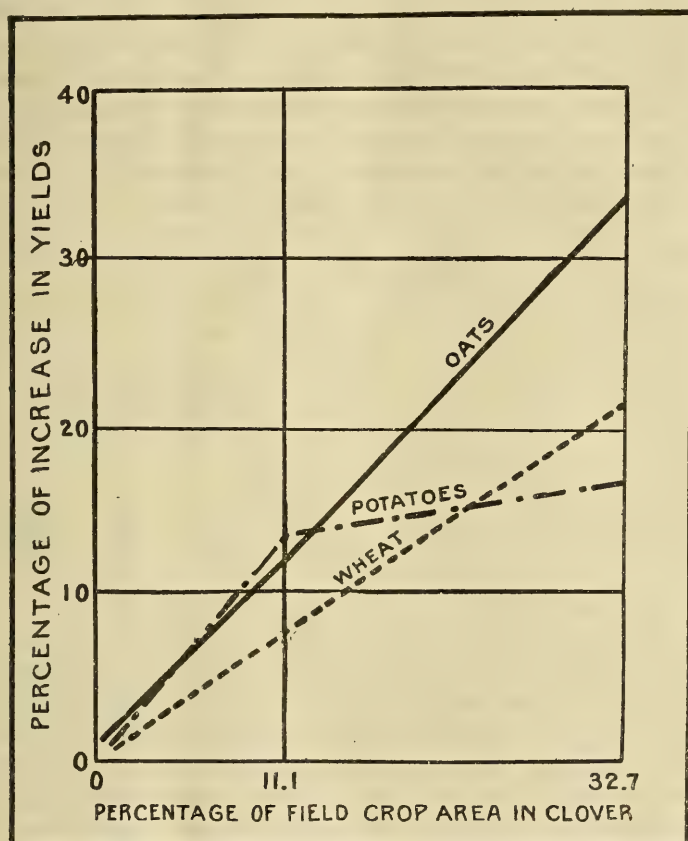


FIG. 5.—Percentage of increase in crop yields with increase in field-crop area in clover on 144 silt loam farms in Marion and Polk Counties, Oreg. (1912).

farms that grew no clover to 113 for the group having over 20 per cent of the field-crop area in clover.

Figure 5 shows the percentage of increase in the yields of potatoes, wheat, and oats for the two groups of farms in Table XII which grew clover, as compared with the yields of these crops for the group of 61 farms having no clover. The average yields of wheat, potatoes, and oats for the group of 45 farms having 11.1 per cent of the field-crop area in clover were 8 per cent, 13 per cent, and 12 per cent higher, respectively, than the yields of these crops for the group of 61 farms

having no clover. Likewise the average yields of potatoes, wheat, and oats for the group of 38 farms having an average of 32.7 per cent of the field-crop area in clover were 17 per cent, 21 per cent, and 33 per cent higher than the yields of these crops for the group having no clover.

RELATION OF SUMMER FALLOW TO CROP YIELDS.

In considering the influence of summer fallow on crop yields, it must be remembered that 40 to 50 years ago the practice of summer fallowing the land once every three or four years was extensively followed in the Willamette Valley on both the clay and silt loam types of soil; that this practice is still generally followed on the clay soil, but has almost disappeared on the silt loam soil. Table XIII shows the comparative yields of potatoes, wheat, oats, and hay on both the clay and silt loam farms with and without summer fallow.

TABLE XIII.—*Relation of summer fallow to crop yields on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Item.	Salem clay.		Salem silt loam.	
	Without summer fallow.	With summer fallow.	Without summer fallow.	With summer fallow.
Number of farms.....	11	57	127	17
Crop yields per acre:				
Potatoes (bushels).....	177.8	192.6	155.9	98.4
Wheat (bushels).....	23.9	25.3	21.9	23.5
Oats (bushels).....	27.0	31.2	37.9	36.5
Hay (tons).....	1.87	2.04	1.94	1.76
Crop index.....	90	101	101	96

From Table XIII it will be noted that 57 of the 68 clay farms had more or less tillable land lying idle as summer fallow, and that only 17 of the 144 silt-loam farms were still practicing the summer-fallow method. The clay farms having summer fallow had higher crop yields than the clay farms having no summer fallow, the relative crop index of the groups with and without summer fallow being 101 and 90, respectively. On the other hand, the silt loam farms having no summer fallow had higher crop yields, for all crops except wheat, than the few farms practicing summer fallowing. Because wheat follows summer fallow, its yield should be affected by summer fallow more than the yield of any other crop. The crop index of the silt loam farms having no summer fallow was 101, whereas that of the 17 farms with summer fallow was 96.

It appears, therefore, that on the silt loam farms having no summer fallow, cropping systems have been adopted that give higher crop yields than are secured on the 17 farms still practicing summer fallowing. This has been accomplished, it is safe to say, by the introduction of the leguminous crops. It is reasonably certain that

clover and other legumes would do as much for the clay-soil farms; for farmers who have been growing clover for a number of years on the clay soil claim that they are getting increased yields.

BARNYARD MANURE AND DRAINAGE.

There are other ways of increasing crop yields besides those brought out by the survey data, among which may be mentioned the use of barnyard manure and drainage. It is a well-recognized principle in agriculture that crop yields on almost any type of soil may be increased by a more liberal use of barnyard manure. Especially is this method of increasing crop yields applicable where the soil has been receiving little animal or vegetable manure. The farmer who adopts this method must see to it that the live stock kept are high-producing animals. He must also use good judgment in marketing his live stock and live-stock products. If this is not done, he may increase his crop yields without increasing his profits.

Much of the agricultural land of the Willamette Valley is so low and level that it is water-logged during much of the time in winter. There probably is no other way by which crop yields on such land can be increased as easily as by drainage. In some localities the individual farm can be drained independently. In other localities the land is so level that it will be necessary to organize drainage districts and work cooperatively in order to get an outlet for the water.

RELATION OF SOIL TYPE TO PERCENTAGE FARM INCOME IS OF CAPITAL.

Table XIV shows the comparative percentages farm income is of capital on the two major types of soil found in the valley. On the 68 clay farms, it will be seen, farm income was 4.35 per cent of the capital invested, as compared with 6.64 per cent on the 144 silt loam farms. That is to say, the silt loam farms were operated 1.52 times as efficiently as the clay farms. The question naturally arises as to the cause of this difference.

TABLE XIV.—*Relation of type of soil to percentage farm income is of capital, on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Item.	Salem clay.	Salem silt loam.
Number of farms.....	68	144
Average area of improved land.....	185	128.5
Average capital invested.....	\$25,330	\$21,457
Average farm income.....	\$1,103	\$1,425
Percentage farm income is of capital.....	4.35	6.64

From Table XIV it will be observed that the clay farms had 56.5 more acres of improved land and \$3,873 more capital to use than had the silt loam farms. Therefore, the difference in the efficiency

of these farms was not due to the lack of capital or usable land on the part of the clay farms. Neither was it due to the difference in the valuation of real estate on the two types of soil, for Table I shows land was worth \$89 per acre on the clay farms and \$112 on the silt loam farms.

CAUSES OF THE DIFFERENCE IN EFFICIENCY.

(1) An average of 73.6 per cent of the farm area of the silt loam farm, as shown by Table I, was improved land, as compared with 71.2 per cent for the clay farms. Thus the silt loam farms have available a slightly higher percentage of improved land.

(2) The silt loam farms produced clover seed, whereas the clay farms produced none. As shown in Table VIII, clover seed in 1912 was a very profitable crop. This contributed materially to the difference in the efficiency of the farms on the two types of soil.

TABLE XV.—*Relation of types of soil to income per productive animal unit and to crop yield on 212 farms in Marion and Polk Counties, Oreg. (1912).*

Item.	Salem clay.	Salem silt loam.
Number of farms.....	68	144
Average income per productive animal unit per farm.....	\$51	\$55
Average productive animal units per farm.....	13.87	13.19
Crop yields per acre:		
Potatoes (bushels).....	187.7	150.2
Oats (bushels).....	30.8	37.7
Wheat (bushels).....	25.2	22.0
Hay (tons).....	2.0	1.9
Crop index <i>a</i>	96	102

a Crop index of this table is based upon the 212 records.

(3) Table XV shows the number of productive animal units per farm, the income per productive animal, and the crop yields on the two types of soil. It will be seen that the clay farms had an average of 13.87 productive animal units per farm, as compared with 13.19 for the silt loam farms; and that the income per productive animal unit was \$4 greater on the silt loam farms than on the clay farms. This would give the silt loam farms an income approximately \$55 per farm greater than that of the clay farms.

(4) From Table XV it will also be seen that potatoes, wheat, and hay, three of the four leading crops upon which crop index in this table is based, gave higher yields on the clay farms than on the silt loam farms. Oats, on the other hand, gave the highest yield on the silt loam farms. However, the crop index of the clay farms was 96 as compared with 102 for the silt loam farms. The difference in the yield of oats on the two types of soil and the large percentage of the rotation area devoted to that crop (see fig. 1) are the causes of the clay farms having the lower crop index. Hence, the difference in the percentage farm income is of capital on the two types of soil

may be attributed, at least in part, to the low yield and large acreage of the oat crop on the clay farms.

(5) Perhaps the greatest cause of the lower efficiency of the clay farms is the practice of summer fallowing approximately one-fourth of the rotation area each year. During the year 1912, 24.5 per cent of the rotation area on the clay farms lay idle as summer fallow, as compared with 2.7 per cent on the silt loam farms (see fig. 1). The practice of summer fallowing diminishes net receipts in two ways. In the first place, the land being summer fallowed represents idle capital from which there is no return. Secondly, the cultivation of the idle land during the summer-fallow year materially increases the operating expenses. On the clay farms 46.1 per cent of the gross receipts were required for operating expenses as against 37.7 per cent on the silt loam farms. The work of cultivating the summer fallow is very largely responsible for this difference.

STARTING CLOVER ON THE CLAY SOIL.

From what has been said in this discussion it should be evident that the profitableness of farming on the clay soil can be greatly increased by adopting cropping systems or rotations that will do away with the summer-fallow practice, and in which clover and other leguminous crops will have a prominent place. Until very recently a very large percentage of the farmers on the clay soil thought this was not feasible. During the last few years, however, many attempts have been made to grow clover on the clay soil. During the season of 1916 a detailed study of 53 trials of growing clover was made in order to determine (1) whether clover can be successfully grown on this type of soil and (2) the most practical ways of getting a stand. The success of the 53 trials, which included 1,111 acres, is shown in Table XVI.

TABLE XVI.—*Results of seeding clover alone and with different nurse crops on Salem clay soil, Marion County, Oreg.*

Nurse crop.	Time of clover seeding.	Number of trials.	Total acres seeded.	Percentage of cases in which the stand was—		
				Good.	Poor.	Failure.
Spring oats.....	Feb., Mar., Apr....	19	392	81.9	10.5	7.6
Spring barley.....	do.....	1	18	100	.....	.....
Spring wheat.....	do.....	4	87	100	.....	.....
Winter wheat.....	do.....	13	202	85.7	11.4	3.0
Do.....	Fall.....	2	70	14.3	.....	85.7
Winter oats.....	March.....	5	107	81.8	7.5	10.7
No nurse crop, clover sown alone.....	May-June.....	9	235	100.0	.....	.....
Total.....	.....	53	1,111	83.8	6.5	9.7

It will be noted that a good stand was secured on 931 acres of the 1,111 acres seeded. In other words, 83.8 per cent of the area seeded gave satisfactory results. A good stand was secured on 100 per cent of the area seeded alone late in May or early in June. A good stand

was also secured on 100 per cent of the area seeded with spring barley and spring wheat. While the number of trials with these two crops is too small to draw very reliable conclusions, studies of starting clover elsewhere show that barley is one of the most satisfactory nurse crops.

The results secured by seeding clover in the spring with spring oats, winter oats, and winter wheat are all that should be expected. The two trials of seeding clover in the fall with winter wheat strongly indicate that that method is unsatisfactory.

METHODS.

From a study of Table XVI three practical methods of starting clover on the clay soil are suggested: (1) Sown alone late in May or early in June; (2) sown with spring grain in the early spring; and (3) sown with winter wheat in the early spring.

1. *Seeding clover alone.*—For seeding clover alone in the late spring the land is plowed quite deep during the winter and kept thoroughly cultivated from early spring until seeding time. About 8 pounds of red-clover seed per acre are sown alone as soon after the 15th of May as weather conditions will permit. The seed is sown broadcast and covered with a harrow or corrugated roller. This is probably the surest method of getting a stand. It should be used only on land that never grew clover before, because the use of the land is practically lost during the year the clover is seeded. Some farmers sow about 5 pounds of rape seed per acre with the clover. The rape makes good sheep, hog, or calf pasture in about six weeks after seeding.

2. *Seeding clover with spring grain.*—When clover is seeded in the early spring with barley, wheat, or oats the land is plowed during the fall or winter and a good, firm, mellow seed bed prepared in the early spring. Eight pounds of red-clover seed per acre are sown late in February or early in March immediately after the grain. The seed is covered with the harrow or corrugated roller, preferably with the roller, as it packs the soil.

3. *Seeding clover in the spring with winter wheat.*—When starting clover with winter wheat about 8 to 10 pounds of seed per acre are sown broadcast late in February or early in March. If wheat has made sufficient growth it is an excellent plan to pasture the field off quickly with sheep. The tramping of the sheep covers the clover seed and packs the ground. After removing the sheep, the field is harrowed to loosen the surface. If no sheep are available, the seed is covered with the harrow.

In starting clover by either of the above methods on land that never produced the crop before, the soil should be as free as possible from weeds. For this reason winter wheat grown on land that was well summer fallowed the previous season makes a good nurse crop. Clover requires a firm, compact seed bed. The corrugated roller is

an excellent implement with which to prepare the seed bed when seeding clover with spring grain. The application of barnyard manure practically insures a stand of clover. The manure should be applied in the fall or winter and plowed under or worked into the soil with a disk harrow.

Inoculation.—The nodule-forming bacteria, that is, the organisms which enable the clover to utilize atmospheric nitrogen, are so essential to the success of clover that land which has never produced this crop should be inoculated. The land to be seeded may be inoculated in two ways; by using a pure culture, or by using soil from a field that successfully produced clover the previous year. The pure culture may be obtained in limited quantities from the United States Department of Agriculture or bought in large quantities from commercial concerns. Directions for use are sent with the cultures.

Inoculation by the soil method should be performed as follows: Locate a patch of clover that grew thriftily the previous year. It may be necessary to go to some farm on the silt loam soil to find it. Collect soil from about plants which bear nodules on their roots. About 1 quart of this soil is placed in a bucket of water and thoroughly stirred. The clover seed is placed upon a tight floor, dampened with the muddy water, using about 2 quarts to each bushel of seed, and shoveled over several times to be sure that each seed is dampened. After the seed has been allowed to dry in the shade (sunlight kills the bacteria) it is ready for seeding. The addition of one-fourth of a pound of glue to each gallon of water will cause the soil to stick to the clover seed.¹

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¹ Very similar methods of seeding clover in the Willamette Valley, Oreg., have been published in Farmers' Bulletin 271, "Forage Crop Practices in Western Oregon and Western Washington," and in Bureau of Plant Industry Circular 28, "Clover Seed Production in the Willamette Valley, Oregon."

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AMERICAN SUMAC: A VALUABLE TANNING MATERIAL AND DYESTUFF.

By F. P. VEITCH, *Chemist in Charge*, and J. S. ROGERS, *Assistant Chemist, Leather and Paper Laboratory*.¹

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INTRODUCTION.

Sumac grows wild on uncultivated lands in a large part of the United States, and is especially abundant and accessible east of the Mississippi River, from Maine to central Georgia and Mississippi. (See Pl. I.) Plentiful stands are found on cut-over land, in old fields, in pastures, on mountain sides, in waste places, and on the edges of swamps in the Appalachian region. Immense quantities of this valuable tanning and dyeing material, which costs nothing to raise, remain ungathered in this country every year, while vegetable tanning materials to the value of more than \$5,000,000² are imported annually. If the sumac industry were well organized, the large quantities of this native tanning and dyeing material now wasted could be utilized in making leather and as a substitute for other dyes wherever practicable. This would serve to check the rising cost of similar tanning and dyeing materials, to lessen our dependence on foreign countries, and to give the country people in certain sections an additional source of employment.

Sumac has long been used in the tanning of leather and in dyeing fabrics. Its value for tanning depends chiefly upon the fact that it yields durable, light-colored or white leathers, and, consequently, it is used largely in the tanning of bookbinding, glove, and hat band leathers, and for removing darker-colored tanning materials from the surface of bag, case, and fair harness leathers. Sumac-tanned leathers have been found to be most durable and suitable for book-

¹ The writers wish to acknowledge the assistance of R. W. Frey of the Bureau of Chemistry in the chemical work connected with this investigation.

² Foreign Commerce and Navigation of the United States, 1916, U. S. Dept. of Commerce.

bindings and other purposes, where the leather must last indefinitely. The greater part of the gathered American sumac, however, is used for dyeing cotton goods.

The sumac industry in the United States is of direct interest to the country people of certain sections. It is largely a farm industry, since the sumac is harvested and cured by the country people, and is sold through country dealers for grinding or for the manufacture of sumac extract.

In recent years the quantity of sumac harvested has been relatively much smaller than formerly. Cheaper materials for making light-colored leathers are in use, while the demands of dyers have not been large. American sumac, owing to careless gathering and curing, yields a darker-colored leather than the sumac imported from Sicily, and, since sumac is used for tanning light-colored leathers, this quality renders the American product less desirable for this purpose and decreases the demand for it. Another reason for the small amount collected is that the gatherers often earned less than could be made at other kinds of work.

Investigations with a view to the betterment of the conditions of collection and the improvement of the quality of American sumac indicate that the reestablishment of the sumac industry in this country on a firmer basis is entirely possible, and is especially desirable at this time, when the importation of Sicilian sumac is restricted by difficulties of transportation.

American sumac, if properly handled, will make an excellent substitute for Sicilian sumac. Consumers of sumac must realize, however, that the first step necessary for the production of a high-grade sumac similar to the foreign article is proper gathering and proper curing, which can be accomplished only by offering as an incentive to the country people a price commensurate with the quality. The better the sumac the better should be the price. In this way mutual benefit will be gained, and much will be done toward materially developing the domestic sumac industry.

Statistics probably do not indicate accurately the quantity of sumac gathered in the United States, because careful records are not kept by gatherers and dealers of the amounts collected and used. The figures for domestic production given in Table 1 were compiled from the Census reports, and the figures for the imports on the reports on commerce and navigation of the United States, issued by the U. S. Department of Commerce.

TABLE 1.—*Production of sumac in the United States.*

Year.	Sumac extract.		Ground sumac.	
	Quantity.	Value.	Quantity.	Value.
	<i>Pounds.</i>		<i>Pounds.</i>	
1899.....	3,349,742	\$103,085	9,284,000	\$114,660
1904.....	4,093,619	95,958	5,061,333	65,190
1909.....	3,148,750	107,476		
1914.....	4,512,361	123,631		

TABLE 2.—*Importation of sumac into the United States.*

Year.	Sumac extract (im- ported for consump- tion).		Ground sumac (gen- eral importation).	
	Quantity.	Value.	Quantity.	Value.
	<i>Pounds.</i>		<i>Pounds.</i>	
1894.....	1,277,609	\$54,535	8,383,570	\$192,647
1899.....	1,266,542	48,369	12,975,970	183,136
1904.....	1,356,020	50,681	18,604,644	276,891
1909.....	1,232,830	54,171	10,974,613	293,249
1910.....	1,461,373	54,899	13,632,861	299,170
1911.....	987,348	36,025		
1912.....	1,389,733	46,551	12,498,376	235,154
1913.....	1,270,825	44,568	14,489,776	297,506
1914.....	1,029,792	42,973	10,770,400	258,738
1915.....	727,449	35,066	13,165,182	323,448
1916.....	36,003	4,108	21,542,360	555,276
1917.....			11,637,023	365,173

Information in the possession of the Bureau of Chemistry shows clearly that the consumption of domestic sumac during the two or three years prior to 1917 has been more than 10,000,000 pounds annually. Early in 1910 domestic sumac was quoted at \$55 per ton. Sicilian sumac is now (May, 1918) worth from \$102 to \$105 per ton at the chief Atlantic ports. Domestic sumac recently (May, 1918) was quoted at \$60 per ton.

SPECIES OF AMERICAN SUMAC.

Important species of sumac growing in North America are: Dwarf sumac (*Rhus copallina* L.), white sumac (*Rhus glabra* L.), staghorn sumac (*Rhus hirta* (L.) Sudw.). Other species which contain tannin are: Fragrant sumac (*Rhus aromatica* Ait.), American smoke tree (*Rhus cotinoides* Nutt.), coral or Jamaica sumac (*Rhus metopium* L.). Two species of sumac are poisonous, namely: Poison sumac, or poison elder (*Rhus vernix* L.), and poison or three-leaf ivy (*Rhus radicans* L.).

Descriptions of the characteristics, together with the geographic distribution, of the more important species follow.

DWARF SUMAC, sometimes called **BLACK** or **MOUNTAIN SUMAC** (*Rhus copallina*).—A shrub or sometimes a small tree with maximum height of 30 feet and trunk diameter of 10 inches. The leaflets are dark green, smooth on top, paler and often hairy underneath, with edges smooth or few-toothed toward the apex. The fruit grows in dense terminal clusters, is crimson in color, and is covered with fine hairs. The unmistakable characteristic of this species is the peculiar winged growth along the leaf stem between the leaflets (Pl. II, A). Dwarf sumac grows in dry soil, and may be found from Maine and southern Ontario to Florida and Texas, and west to Minnesota and Nebraska.

WHITE SUMAC, sometimes called **SMOOTH**, **UPLAND**, or **SCARLET SUMAC** (*Rhus glabra*).—A shrub, or rarely a small tree, 2 to 20 feet high. The leaflets are dark green on top and whitish underneath, with edges sharply saw-toothed. The fruit grows in dense terminal

clusters, and is covered with short reddish hairs. The distinguishing characteristics of this species are the smoothness of the stalks and leaf stems, together with a bluish white bloom, a powdery film similar in appearance to that found on plums, which covers them and the under side of the leaflets (Pl. III). White sumac grows in dry soil from Nova Scotia to British Columbia, and south to Florida, Mississippi, and Arizona.

STAGHORN SUMAC, sometimes called HAIRY SUMAC (*Rhus hirta*, L.).—A shrub, or small tree, with maximum height of 40 feet and trunk diameter of 9 inches. Leaflets, dark green and nearly smooth on top, pale, and more or less hairy underneath, with edges sharply saw-toothed. The fruit, which grows in dense terminal clusters, is thickly covered with bright crimson hairs. The distinguishing characteristic of this species is the hairy growth along the stalks and leaf stems (Pl. IV). Staghorn sumac is found in dry and rocky soils from Nova Scotia to Georgia, especially among the mountains, and as far west as southern Ontario, Minnesota, Missouri, and Mississippi.

Since poison sumac sometimes is mistaken for the more common species, and its poisonous effects are usually very severe, it seems desirable to describe it as an aid in distinguishing poison sumac from the other species.

POISON SUMAC, sometimes called POISON ELDER (*Rhus vernix*, L.).—A shrub, or small tree, with maximum height of 28 feet and trunk diameter of 6 inches. The leaflets are green on top and underneath, with edges smooth. The fruit, which grows in loose, open clusters, consists of smooth white or light gray berries. It should be noted that poison sumac differs decidedly from the important species in the color and cluster formation of its fruit. Furthermore, it may be easily distinguished from the dwarf sumac by the absence of the winged growth along the leaf stems, and from the white and staghorn sumac by its smooth-edged leaflets (Pl. V). Poison sumac almost invariably is found in swamps. It grows from southern Ontario and near the eastern coast in the Eastern and Middle States, south to Florida, and west to Minnesota, Missouri, and Louisiana.

PRESENT METHODS OF GATHERING AND CURING AMERICAN SUMAC.

COMMON NAMES USED BY GATHERERS.

Sumac is commonly termed by the gatherers either "black" or "white." "Black" sumac refers to dwarf sumac (*Rhus copallina*), and "white" sumac usually means white sumac (*Rhus glabra*), although it is believed that this term is sometimes applied also to staghorn sumac (*Rhus hirta*). *Rhus hirta* is not so extensively gathered as *Rhus glabra*. In some sections, as in eastern Virginia, only the dwarf sumac is collected, while in others, such as the western part of Virginia and in West Virginia, Maryland, and Pennsylvania, both dwarf and white sumac are gathered.

KINDS AND CONDITION OF SUMAC DESIRED BY EXTRACT MANUFACTURERS.

In eastern Virginia the dwarf sumac only is accepted, other species being positively refused. All contracts with gatherers specify that the sumac shall be of the dwarf species only. The leaves, leaf stems, and new growth of stalks if broken immediately below the lowest leaf stem are acceptable. The reason given in eastern Virginia for not receiving the white species is that it contains a much larger proportion of pithy, milky stalks, and yields less extract.

In western Maryland, Pennsylvania, and West Virginia, and, in fact, generally in the sections which supply northern mills, the leaves and leaf stems of all varieties, mixed or unmixed, are equally acceptable.

PROPER TIME TO GATHER.

Extract makers are opposed to the early gathering of sumac, even though the leaves apparently are mature. They state that the leaves gathered in May and June are light weight, do not yield as much extract, and can not be handled as well in the extracting process. From the viewpoint of both gatherers and extract makers, the best time to gather sumac is in July, August, and September. Gathering may be continued until frost. The dropping off of the leaves, however, constitutes a loss, while the color of the extract made from red or poorly cured leaves is darker and less desirable than that made from light-colored, well-cured leaves.

YIELDS PER ACRE.

While sumac is very plentiful, especially in the eastern United States, it rarely covers thickly an area of any extent, but, intermingled with other vegetation, grows rather scattered in patches along old fence rows, and on cut-over and burned-over woodland. Reports have been received that in certain sections it grows thickly, unmixed with other growth, and in sufficient areas to permit cutting with a mowing machine. Several cases of clean stand have been reported, but they have not come directly to the attention of the Bureau of Chemistry. A report has been received from eastern Virginia of a tract of from 10 to 15 acres of burned-over and cut-over land from which 5 tons of dwarf sumac (leaves, leaf stems, and current year's stalk) were gathered. An estimate by the bureau, based on the material gathered from a measured area 20 by 30 feet of white sumac, gave a calculated yield of 4,864 pounds (green weight) per acre. This would give about 1,621 pounds of cured sumac.

QUANTITY A MAN CAN GATHER IN ONE DAY.

Many factors may influence the quantity a man can gather. Some of these are the experience and alacrity of the gatherer, availability or lack of teams for hauling, growth of sumac—whether dense or

scattering—species of sumac collected, and whether leaves, leaf stems, and stalks, or only leaves and leaf stems are desired. The amount of sumac collected by one man in one day may weigh from 150 to 600 pounds when dried, but averages between 200 and 300 pounds. From experiments conducted by the bureau, in which the sumac was collected by an experienced gatherer, it has been estimated that the following amounts of sumac (leaves, leaf stems, and stalks combined) can be gathered in one eight-hour day by an energetic man, provided the stand is good, so that little time is lost in going from one patch to another:

Dwarf—728 pounds green; loss of water in curing, 54 per cent; cured sumac, 335 pounds.¹

White—1,744 pounds green; loss of water in curing, 67 per cent; cured sumac 576 pounds.

Staghorn—952 pounds green; loss of water in curing, 58 per cent; cured sumac, 400 pounds.

Where the stand is scattering or the gatherer is slow, the quantity gathered will be less, but in no case should an able-bodied man be satisfied with less than 200 pounds of cured sumac (leaves and stalks) from his day's work

GATHERING AND CURING.

The general practice followed in gathering is to break or cut (only the black can be broken readily) the new-growth stalk just below the lowest leaf stem. The sumac is then allowed to wilt in the sun for a few hours or a day, and hauled to a barn, where it is spread on the barn floor in a layer of from 1 to 3 feet in depth, or on racks which permit the circulation of air underneath. The sumac is then turned once or twice each day for a week to aid in the drying and to prevent the leaves from molding. Some gatherers do not let the sumac wilt in the sun, but spread it at once on racks in the barn or under cover. This method aids materially in producing sumac of the lightest and best color.

LOSS IN CURING AND HANDLING.

Experienced gatherers estimate that the green sumac loses from 50 to 60 per cent in weight during curing. There is still further loss in weight between the time of purchase by the dealer and the time of sale, due largely to loss of moisture, still present because of incomplete drying, to falling of leaves, and to the removal of adhering dirt. This loss between the purchase and sale by the dealer varies in amount from 5 to 15 per cent, thus making a total loss in weight from the original green sumac of from 60 to 75 per cent.

Results of laboratory experiments on the curing of sumac (leaves, leaf stems, and stalks) given in Table 3 show losses while curing which agree well with those estimated by gatherers.

¹ The dwarf sumac was more scattered than the other two varieties. This may account for the comparatively low figures for this species.

TABLE 3.—*Loss of moisture in curing sumac (collected Sept. 28, 1916).*

Species.	Duration of drying.	Loss of moisture.
	<i>Days.</i>	<i>Per cent.</i>
Dwarf.....	5	50.5
	25	53.2
	49	53.6
White.....	5	63.9
	25	66.1
	49	66.6
Staghorn.....	5	55.5
	25	57.3
	49	57.8

There is reason to believe that the loss in curing on the farm is not so great as the loss observed in the bureau's experiments, where the sumac dried out very thoroughly. The total loss in weight of the mixed leaf and stalks from gathering until it reaches the extract maker probably averages very close to 60 per cent.

PREPARATION FOR TRANSPORTATION.

Sumac received by the dealers from the farmers usually comes in bags, or is handled loose in wagonloads like hay, and in many instances may have been hauled as far as 20 miles. Many farmers prefer to deliver the sumac in wagonloads, as they claim that too much time is consumed by putting it up in bags. Since the sumac becomes very brittle when dried and the leaflets are easily broken from the leaf stems, much loss occurs in handling it loose. Dealers, therefore, as a rule, prefer to have the sumac delivered in bags. These bags cost the dealers 8 to 9 cents each, but are usually furnished without cost to the gatherers. Some gatherers, after drying the sumac, flail off the leaves and pack them in bags for shipment. Seventy-five pounds should be packed into a 4-bushel bag, but the average quantity put into them is about 40 pounds.

From the small dealers to the extract manufacturers the sumac is usually handled in bags or bales. The cost of baling is about 10 cents per hundredweight.

PRICES PAID GATHERERS AND DEALERS.

During the seasons of 1916 and 1917 in eastern Virginia the gatherers received from 90 cents to \$1 per 100 pounds in trade from the dealers. The extract manufacturers furnished bags for use in hauling and shipping the cured sumac. The dealers received from the extract makers \$1.10 per 100 pounds for the bagged or baled material, which in this region includes the new-growth stalks as well as the leaves and leaf stems. In northern West Virginia and western Maryland the gatherers received in 1916 for the leaves and leaf stems alone (no stalks) from 80 cents to \$1 per hundred pounds in trade from the dealers, who in turn received \$1.10 to \$1.15 from the extract makers. In 1917 these prices were about 5 cents per hundred higher. In this section all varieties of sumac are mixed and well packed for shipment in bags furnished free of charge by dealers.

TANNIN CONTENT OF AMERICAN SUMAC.

The leaves and leaf stems together of the three most important American sumacs—dwarf, white, and staghorn—when air-dried, contain approximately the same amount of tannin—that is, from 25 to 35 per cent.¹ The leaves of fragrant sumac are said to contain 13 per cent tannin, of American smoke-tree 21 per cent, and of coral sumac 8 per cent. Usually the quantity of tannin appears to be somewhat greater later in the season than in June and early July. The leaves contain the highest percentage of tannin after they are fully grown and before they begin to turn yellow or red.

Analyses made in the Leather and Paper Laboratory of the Bureau of Chemistry of various samples of sumac gathered in Virginia, West Virginia, Maryland, and Pennsylvania gave the following results:

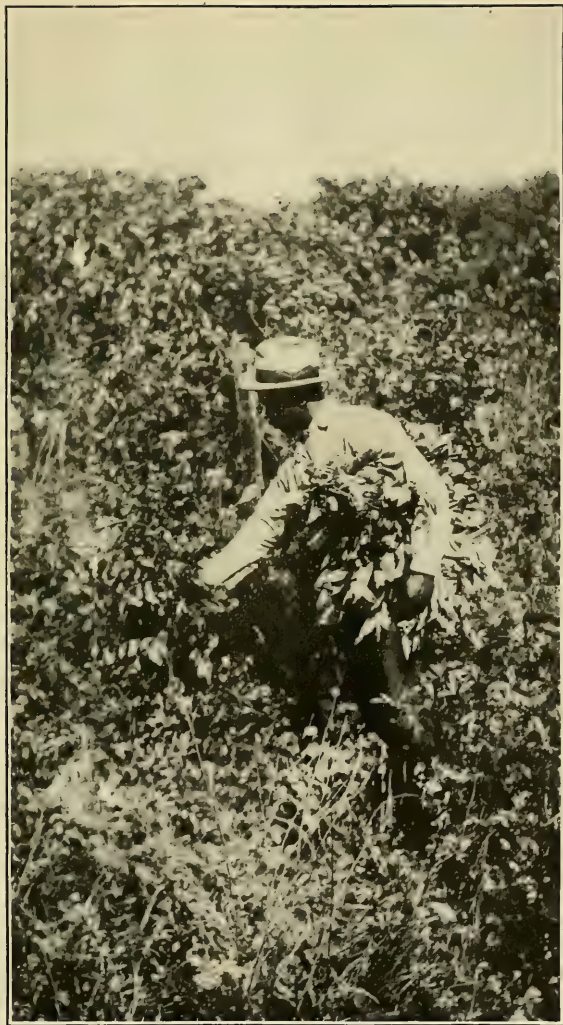
TABLE 4.—*Tannin content of samples of dwarf, white, and staghorn sumac.*

Species.	Tannin in leaves and leaf stems.			Tannin in stalks.		
	Average.	Maximum.	Minimum.	Average.	Maximum.	Minimum.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Dwarf.....	28.95	35.03	19.46	7.77	9.94	5.09
White.....	25.14	28.08	21.35	6.84	7.30	6.19
Staghorn.....	27.66	30.59	21.53	7.07	8.09	6.45

Dwarf sumac, it will be seen, contains somewhat more tannin than staghorn or white sumac. This bears out in a general way the statement of buyers in eastern Virginia, though this difference is of itself not great enough to justify the refusal of the white. The sumac samples analyzed were found to average 73.3 per cent leaves and leaf stems and 26.7 per cent stalks. The variation, however, was marked, extending, in the case of the leaves and leaf stems, from 54 to 89 per cent, and, for the stalks, from 11 to 16 per cent. The large proportion of stalks indicated by the percentage last given should never be permitted. Gatherers must be careful to break the stalk close to the lowest leaf stem, and not to gather the long stalk bare of leaves. If the stalks are broken close to the leaf stems, the sumac will usually meet the buyers' demands. Dealers and extract makers very properly insist that the sumac as delivered shall not contain on an average more than 25 per cent of stalks.

The portions of the plant usually considered of value for tanning and dyeing purposes are the leaves and leaf stems, although, as shown in Table 4, the stalks contain from 5 to 10 per cent tannin, an amount entirely too large to discard after the trouble and expense of collecting and hauling to market has been incurred. This tannin should be recovered, as an extract could be made from the stalks

¹ These figures apply more particularly to Virginia, West Virginia, Maryland, and Pennsylvania sumacs.



GATHERING DWARF SUMAC.



DWARF SUMAC.



WHITE SUMAC.



STAGHORN SUMAC.



POISON SUMAC.

and off-colored leaves that would be satisfactory for tanning and dyeing purposes when color is not the primary consideration.

Some extracts made from American sumac show the same results upon analysis as those made from the best Sicilian sumac, and contain coloring matter not more than 20 per cent in excess of that found in Sicilian sumac extracts. They can be bought at about three-fifths the price paid for extracts made from Sicilian sumac.

SUMAC EXTRACT.

Formerly the users of domestic sumac bought the leaves or ground sumac, which is the sumac leaf ground to a coarse powder, and made their own liquors for tanning or dyeing from these materials. In recent years the grinding of sumac has decreased, and users have bought sumac extracts instead. The price of domestic sumac extract, which contains usually about 25 per cent of tannin and is sold on the basis of its tannin content, has increased materially in the past three years. In 1914 the quoted price per pound was about $3\frac{3}{4}$ cents; in 1915, from $3\frac{3}{4}$ to 9 cents; in 1916, from $5\frac{1}{2}$ to 10 cents; in 1917, from $4\frac{1}{2}$ to 5 cents; and at present (May, 1918), the price is $4\frac{1}{2}$ to 5 cents per pound. A pound of extract contains approximately the same amount of tannin as a pound of sumac leaf, if anything somewhat less than a pound of the properly gathered and cured leaf.

In making sumac extract the tannin is extracted with large quantities of water which must be evaporated in expensive copper pans under skilled supervision and at some expense for fuel. When the extract is to be used, as much or more water than was evaporated in making it is added to secure a tanning or dyeing solution of the desired strength.

DISPOSAL OF EXTRACTED MATERIAL.

So far as can be learned, no really useful method of disposing of the extracted leaves is in general use. The material is placed in large piles or ricks, or used to fill in waste places. A small quantity is used on farm land as a top-dressing to be plowed under. Analyses of the commercially extracted material given in Table 5 show its fertilizing value.

TABLE 5.—*Fertilizing value of commercially extracted sumac leaves and leaf stems and stalks.*

Sample No.	Part of plant.	Moisture.	Calcium oxid.	Potassium oxid.	Phosphorus pentoxid.	Ash.			
						Total.	Calcium oxid.	Potassium oxid.	Phosphorus pentoxid.
32479.....	Leaves and leaf stems.....	<i>Per cent.</i> 5.70	<i>Per cent.</i> 1.66	<i>Per cent.</i> 0.11	<i>Per cent.</i> 0.23	<i>Per cent.</i> 5.13	<i>Per cent.</i> 32.36	<i>Per cent.</i> 2.14	<i>Per cent.</i> 4.48
32482.....	do.....	5.33	1.95	.09	.20	5.32	36.65	1.69	3.76
32479.....	Stalks.....	4.59	1.31	.39	.15	3.43	38.19	11.37	4.37
32482.....	do.....	4.59	1.44	.17	.11	3.24	41.36	5.24	3.39

Examination of a number of unextracted sumac samples gave: Ash, 4 to 7.5 per cent; potassium oxid, 1.18 to 2.15 per cent. The ash of these samples contained from 25 to 30 per cent of potassium oxid.

Comparison of the percentage of potassium oxid (K_2O) in the original material and in the water extract, as obtained for the tannin analysis, shows that although the unextracted sumac contains rather high percentages of potassium oxid, as is to be expected, this is almost entirely removed on extraction. These experiments were made on finely ground sumac leaves and leaf stems, whereas in commercial practice the extraction generally is made on the unground leaves and stalks, and consequently is not so thorough, especially in the case of the large stalks. This practice of making extraction on the unground leaves and stalks undoubtedly accounts for the comparatively high percentages of potassium oxid in the samples of commercially extracted stalks, analyses of which are given in Table 5.

Except for the organic matter which it contains, extracted sumac has comparatively little value for the farmer. However, in sections where sumac is gathered, where the land is usually deficient in organic matter, the extracted material can be profitably hauled a mile or two, especially if before scattering on the land it can be mixed and rotted with barnyard manure.

CAUSES OF POOR QUALITY IN SUMAC.

Lack of care and attention to details in gathering and curing results in sumac of inferior quality. Undue exposure to the sun or any exposure to dew or rain while green, and heating and molding resulting from too deep layers and insufficient turning during curing, cause a decided darkening of the leaves and materially reduce the percentage of tannin. The presence of stalks and red leaves in cured sumac is objectionable, because they produce an undesirable color on leather. Furthermore, since the stalks contain only about one-fourth as much tannin as the leaves, their presence gives the mixture a lower tannin content. The presence of dirt or sand in cured sumac also is objectionable, for it increases the weight without increasing the tannin content, and leathers tanned with such sumac will darken because of the iron present.

COOPERATION FOR BETTER SUMAC.

One of the objects of this bulletin is to point out the necessity for helpful cooperation between gatherers, dealers, and extract makers, with a view to the production of higher-grade sumac and sumac extracts and the payment of higher prices to the gatherers for better sumac. This cooperation can be successfully maintained only if it is mutually beneficial. The initiative and success rest with the final buyers, the extract makers, who, by offering a bonus for "extra" quality sumac, can encourage the gatherers to make special efforts

to produce a high-grade, bright, clean product. It is suggested that dealers and buyers keep on hand suitable samples, one to be known as "Standard," for which they will pay the regular price, and another as "Extra," for which a bonus of 15 to 30 cents per hundred will be paid, for the information and guidance of gatherers. Sumac materially below "Standard" in color or quality should be bought only at a reduction. If the directions for gathering and curing given in this bulletin are carefully followed, no sumac below "Standard" will be produced, while much of it will be of "Extra" quality.

DIRECTIONS FOR THE PROPER GATHERING AND CURING OF SUMAC.

In order to obtain sumac of the best quality, both as to color and percentage of tannin, carefully follow these directions:

Gather only dwarf, white, and staghorn sumacs (Pls. I, II, and III). Break the stalk bearing the leaves and leaf stems just below the lowest leaf stem; or, better, gather only the leaves and leaf stems. Harvest during June, July, August, and September, and avoid the collection of red or yellow leaves. As soon as gathered, place the sumac in the shade or under a canvas cover, which permits the air to get to it, and avoids undue exposure to the sun. Do not allow it to be wet by dew or rain, and at the end of each day haul the gathered sumac to a barn or open shed, where it should be spread in layers not over 1½ feet deep upon a clean floor, or upon open racks which will permit ready access of air. Turn the layers over once or twice daily for from one to two weeks, or until thoroughly dry. In case the leaves have been gathered with stalks, separate these from the leaves and leaf stems by flailing and forking out. Do not allow the gathered sumac to come in contact with the bare ground at any time, as dirt injures the quality. The leaves thus prepared should be of a uniformly light green color. Pack tightly in bags and keep in a well-aired, dry loft until sold.

BUYERS OF SUMAC.

Sumac, when properly cured, usually can be sold to merchants in towns or cities near the place where it has been gathered, or it can be sold directly to manufacturers who buy sumac for grinding or for the preparation of sumac extract. Before starting to gather, however, the gatherer should have a definite understanding and contract with the dealer as to the quantity which he will buy from him; the price which will be paid; how the sumac is to be delivered; arrangements for a supply of bags, if it is to be delivered in bags; and especially as to the extra price to be paid for exceptionally bright, well-cured sumac. If the names of dealers are not obtained by inquiry of merchants, hide dealers, or others in near-by towns or cities, this

information can be obtained from the various State agricultural experiment stations or from the Bureau of Chemistry, United States Department of Agriculture, Washington, D. C.

SUMMARY.

Sumac grows wild and abundantly on uncultivated lands, particularly east of the Mississippi River. Country people, especially the elderly and women and children, can make good wages from June to September by gathering and curing sumac. Imported sumac is scarce and high priced. Domestic sumac, if properly gathered and cured, can be largely substituted for imported, and should bring better prices than domestic sumac as now cured.

Before beginning to gather sumac be sure to arrange fully and clearly with the dealers as to: (1) The quantity which they will buy from you; (2) a supply of bags; (3) the price per hundred pounds; and especially (4) *an extra price for well-cured sumac leaf*.

Practically the only kinds of sumac gathered in this country are dwarf (*Rhus copallina* L.), white (*Rhus glabra* L.), and staghorn (*Rhus hirta* (L.) Sudw.).

Domestic sumac as now prepared for market contains less tannin, and is much inferior in color to imported Sicilian sumac.

Properly gathered and cured domestic sumac leaf contains from 25 to 30 per cent of tannin, practically as much as Sicilian sumac leaf.

Owing chiefly to low quality, due to careless gathering and curing, the gatherer has received in recent years a low price for sumac, from 60 cents to \$1.10 per 100 pounds. Carefully gathered and properly cured Sicilian sumac leaf sells in this country at from \$2.50 to \$4 per 100 pounds.

A better product, both in color and tannin content, is obtained by proper gathering and curing and by the separation of the stalks.

Domestic sumac extract, containing 25 per cent of tannin, in 1914 sold at about 3 $\frac{3}{4}$ cents; 1915, from 3 $\frac{3}{4}$ to 9 cents; 1916, from 5 $\frac{1}{2}$ to 10 cents; 1917, from 4 $\frac{1}{2}$ to 5 cents; May, 1918, 4 $\frac{1}{2}$ to 5 cents per pound.

The development of the American sumac industry and the production of bright, uniformly and properly cured domestic sumac can be accomplished only through the earnest and whole-hearted cooperation of the buyers and the gatherers. The buyers must make every effort to stimulate the proper gathering and curing by offering better prices and through careful instructions in proper methods of gathering, curing, and packing. The gatherers must respond by following exactly the directions set forth in this bulletin and the instructions and advice given by the buyers.

Gatherers should consult their State experiment station for the names and addresses of buyers of sumac and of sumac extract makers.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 707

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief



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RESULTS OF EXPERIMENTS WITH MISCELLANEOUS
SUBSTANCES AGAINST BEDBUGS, COCKROACHES,
CLOTHES MOTHS, AND CARPET BEETLES.

By E. W. SCOTT, *Entomologist, Enforcement Insecticide Act*, and W. S. ABBOTT
and J. E. DUDLEY, Jr., *Scientific Assistants, Bureau of Entomology*.

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INTRODUCTION.

In connection with the enforcement of the insecticide act of 1910, numerous substances entering into the composition of proprietary insecticides have been tested against many different insects, resulting in the accumulation of a large amount of data relative to the efficacy of such substances. This work is conducted at the Insecticide Board's Testing Laboratory, located at Vienna, Va., and directed by Dr. A. L. Quaintance, of the Bureau of Entomology.

This paper, the first of several to be published on the results of such tests, presents data on the efficacy of various substances, used alone and in combination, against bedbugs, cockroaches, clothes moths, and carpet beetles.

BEDBUGS.

METHODS OF TESTING.

The tests of various materials, in many cases of previously undetermined insecticidal value, against the bedbug (*Cimex lectularius* L.), are of two general types, (1) jar tests and (2) room tests. In the former 20 bedbugs were confined in a pint jar with paper scraps or excelsior to furnish hiding-places, and thoroughly dusted or sprayed with the material to be tested, after which the jars were covered with cheesecloth. At least two of these jars were used in each test. Records were taken at the end of 24 hours, and as often thereafter as was considered necessary. With each series of tests two similar jars, each containing 20 bedbugs and paper scraps or excelsior, were used as a check. If the mortality in these checks ran above 35 per cent the whole series was discarded, except in those cases where the mortality in the treated jars was 10 per cent or less. No food was furnished in any of these tests, but it should be noted that in many cases the experiments were continued for two weeks with a mortality of less than 10 per cent in the checks.

This method of testing, although admittedly very severe on the bugs, and not simulating natural conditions, was used primarily to ascertain whether the given insecticide material would kill the insects and was not intended to determine its exact value under practical conditions.

Experiments on a practical scale were made by thoroughly dusting badly infested rooms or beds with the material to be tested. In these experiments the room or bed was examined only once, usually four or seven days after treatment.

KILLING EFFECTS OF LIQUIDS AGAINST BEDBUGS.

HYDROCARBON OILS.

Twenty-seven different hydrocarbon-oil preparations, composed largely of oils of the nature of kerosene and gasoline mixed with varying amounts of nitrobenzene, phenols, essential oils, etc., were tested. All of these were found to be very effective, most of them killing 100 per cent of the treated insects within 24 hours.

As remedies against bedbugs, the oil sprays possess one very great advantage over other insecticides—their power of penetration. With powders and most liquids it is very difficult, if not impossible, to reach the bugs, which are generally hidden during the day in cracks and holes in the beds, behind wall paper and moldings, or in the bedding itself, and in these places they are readily reached by the heavier oils. These sprays possess the added advantage of de-

stroying the eggs whenever they come in contact with them, and here, also, their powers of penetration greatly increase their practical effectiveness.

The preparations composed largely of oils of the nature of gasoline were found, in jar tests, to be as effective as the kerosene sprays, but because of very rapid evaporation they are not as valuable under practical conditions as are those composed of a heavier oil, and it has been found that gasoline, at least under certain conditions, is not effective against bedbug eggs. (See p. 7.)

COAL-TAR CREOSOTE EMULSIONS.

Numerous tests with coal-tar creosote emulsions indicate roughly that the effectiveness of this class of materials depends on two factors: (1) The dilution, and (2) the amount of water present in the original emulsion. When used undiluted, these emulsions killed from 95 to 100 per cent in 24 hours, but when diluted 1 to 30 or more, in no case were all of the insects killed, although many of the tests were continued for seven days.

MERCURIC CHLORID.

Table I gives the results of tests with mercuric chlorid against bedbugs.

TABLE I.—*Results of tests with mercuric chlorid used as spray against bedbugs confined in jars.*

Test No.	Per cent mercuric chlorid.	Other ingredients.	Number used.	Duration of test.	Per cent dead.	Un-treated, per cent dead.
				<i>Days.</i>		
1.....	0.23	Water.....	40	4	10	10
2.....	.50	do.....	80	8	39	15
3.....	1.00	do.....	120	4-8	20-53	7.5
4.....	1.09	Alcohol.....	120	5	70	30
5.....	1.35	Alum, salt, water.....	65	12	75-100	23
6.....	2.00	Water.....	80	8	58	15
7.....	4.00	do.....	80	8	77	0
8.....	5.72	Water, alcohol, phenol 1.44 per cent.....	40	6	45-95	13
9.....	6.00	Water.....	40	1	100	35

Table I shows that mercuric chlorid, even in a 2 per cent solution, is somewhat effective, and that a 6 per cent solution killed 100 per cent of the treated bugs within 24 hours.

As mercuric chlorid is a very violent poison, its use ordinarily would be attended with considerable danger, but in solution a small amount can be used effectively without serious danger of accidental poisoning. In solution it also can be more thoroughly applied and forced into cracks and holes, so that, on drying, it leaves a thin film of poison which will remain to kill any bugs not hit by the spray.

EXPERIMENTS WITH POWDERS AND OTHER MATERIALS.

PYRETHRUM.¹

Tests with 28 different samples of pyrethrum have been made and all samples were found to be very effective against bedbugs in jar tests.

These tests also show that there is no practical difference in effectiveness between powder made from the buds, half-open flowers, half-closed flowers, and closed flowers, or between the cultivated and wild flowers. Tests made during 1912 with powders made from 1908, 1909, and 1910 crops of flowers showed no practical difference in their efficiency, which indicates that pyrethrum does not deteriorate materially in four years.

The actual effect of pyrethrum on bedbugs is to render the insects inactive almost at once, and, although slight movements of the legs and antennæ may continue for several days, the insects do not recover.

Under the conditions of jar tests five samples, consisting wholly or largely of pyrethrum stems, were found to be of comparatively little value. In the one-room test made with powdered stems they appeared to be absolutely ineffective. In this test a grossly infested bed was thoroughly dusted, and four days after treatment careful search failed to locate a single dead bug, either in the bed or on the floor. Many living bugs were found in cracks where the powder was still plainly visible, and some were seen crawling about with their backs still covered with it.

TOBACCO POWDERS.

A number of tests were made with tobacco powders against bedbugs dusted in jars, and it was found that powders containing as high as 3.41 per cent, 3.73 per cent, and 5.26 per cent nicotine did not kill all of the treated insects in 12 days.

HELLEBORE.

Not one of the seven different lots of hellebore tested was of value against bedbugs.

This would appear to indicate that hellebore is of no value as a contact insecticide, and this conclusion is greatly strengthened by the fact that it was found to be ineffective against 12 different species of other sucking insects.

¹ A powder made by grinding to an impalpable powder the flower heads of a *chrysanthemum*, *Pyrethrum cinerariaefolium* and *P. roseum*. The manufactured product has been sold also as "buhach," Persian insect powder, and Dalmatian insect powder.

POWDERED MIXTURES CONTAINING MORE THAN ONE ACTIVE INGREDIENT.

A number of jar tests have been made with 20 miscellaneous powders containing small amounts of nicotine, naphthalene, pyrethrum, and various oils as active ingredients. These powders were more or less effective, depending on the amount of the active ingredients present.

MISCELLANEOUS MATERIALS.

The following materials were found to be more or less effective against bedbugs, killing from 80 to 100 per cent in jar tests:

Miscellaneous materials more or less effective against bedbugs.

Material.	Form of preparation.	Killed.
		<i>Per cent.</i>
Acetic acid.....	50 per cent solution.....	100
Ammonia water.....	Undiluted.....	80
Coal-tar oil, chlorinated.....	do.....	100
Cottonseed oil.....	10 per cent mixture.....	93
Glycerol.....	Undiluted.....	100
Kerosene.....	10 per cent mixture.....	100
Linseed oil.....	do.....	94
Nicotine (40 per cent, as sulphate).....	1-32.....	80-90
Do.....	1-64.....	80-95
Pine needles, oil of.....	10 per cent mixture.....	100
Sabadilla seeds.....	Dust.....	100
Turpentine, crude wood.....	Undiluted.....	100
Mercuric chlorid.....	Dust.....	100

These data show little of interest, except the efficiency of sabadilla seeds (*Sabadilla officinalis* Brandt). These seeds or extracts are largely used in remedies for vermin on the human body, especially in the hair, but their use against bedbugs is rather unusual. In five tests they proved to be very effective, killing from 95 to 100 per cent in 48 hours.

Mercuric chlorid, used as a dust, killed all of the treated insects, but this material is too poisonous for general use in houses.

The following is a list of various materials which were found to be ineffective against bedbugs. The method of testing is indicated in parentheses.

Materials found ineffective against bedbugs.

Allspice (jar).	Formaldehyde (room, 8.87 per cent solution, sprayed twice, 1 part to 14 parts water).
Alum (jar).	Lead acetate (jar).
Angelica root (jar and room).	Paris green (jar).
Arsenious acid (jar).	Pepper, red (jar).
Borax (jar).	Quassia chips (jar and room).
Boracic acid (jar).	Sodium bicarbonate (jar).
Chamomile flowers (jar).	Sodium fluorid (jar and room).
Colocynth pulp (jar).	
Eucalyptus leaves (jar and room).	

The principal fact of interest in these data is that such violent stomach poisons as arsenious oxid and Paris green were found to be ineffective, as were also the milder sodium fluorid, lead acetate, borax, and boracic acid. These results show conclusively that bedbugs can be controlled only by an insecticide which acts directly on the body, and that none of the materials with which the insect comes in contact is taken into the stomach.

Although, in a few cases, these materials appeared to have some slight effect on the insects, the number killed was so small that they would be of no value under practical conditions.

PHOSPHORUS PASTES.

Two tests were made with pastes formed of sugar, water, and starchy material, and containing, in one case, 1.91 per cent and, in the other, 2.21 per cent of phosphorus. The first test was made in a room badly infested with bedbugs, and the paste was liberally smeared in the corners of the bedstead and in the cracks around the baseboards and moldings. Observations were made several days after treatment, and it was then evident that this material was of no value. Hundreds of living bugs were present, and the only dead ones seen were a very few that had become entangled in the paste and stuck fast.

In the second test the paste was smeared on pieces of paper and placed in a box containing 50 bedbugs. One week later examination showed that 90 per cent of the insects were still living and active.

FUMIGATION AGAINST BEDBUGS.

Results obtained in a limited number of tests made with sulphur as a fumigant show that it will kill bedbugs, and indicate that the necessary amount for effective use is at least 1 pound to 1,000 cubic feet of room space.

Not only is sulphur fumigation effective against the bedbugs themselves, but it has been found by several workers to kill the eggs also, which makes it a very satisfactory method of fighting this insect. This effectiveness against the eggs is of particular importance, since they are often deposited in inaccessible cracks and holes, or behind wall paper, where it is very difficult, or even impossible, to reach them with a dust or spray.

The following materials were found to be ineffective as fumigants against bedbugs when used at the rate indicated:

Paradichlorobenzene (8.5 pounds to 1,000 cubic feet).

Paraformaldehyde (2.25 pounds to 1,000 cubic feet).

Charcoal (1.64 pounds to 1,000 cubic feet).

TESTS AGAINST BEDBUG EGGS.

The eggs used in these experiments had been deposited on pieces of paper or cloth. These were thoroughly sprayed or dusted with the materials to be tested and then placed in jars covered with cheese-cloth. Kerosene oil was the only material used which was found to be completely effective, not one of the eggs sprayed with this material hatching. The fact that the eggs sprayed with gasoline apparently hatched in a perfectly normal manner indicates that this material, although effective against bedbugs, vaporizes so rapidly that it does not penetrate the eggshell and reach the embryo, and that the evaporation is so complete that not enough oil remains, at the end of six days, to kill the newly hatched insects.

Mercuric chlorid, either as a dust or in a 1.35 per cent spray, appeared to have no effect on the eggs, as the young bugs emerged at approximately the same time as those from the untreated eggs. Where this material was applied as a dust, enough was present to kill all of the insects as soon as they had left the eggs, but the amount left by the 1.35 per cent solution apparently was not great enough to kill them.

SUMMARY.

1. The hydrocarbon oil sprays were found to be very effective against bedbugs, killing, in most cases, 100 per cent within 48 hours.

2. Coal-tar creosote emulsions were effective, when used undiluted, but their effectiveness fell very rapidly when they were diluted.

3. Mercuric chlorid, as a dust and in a 6 per cent water solution, was found to kill 100 per cent of the treated insects.

4. Pyrethrum was found to be very effective against bedbugs, while pyrethrum stems were of little or no practical value.

5. Tobacco powders, containing as high as 5.26 per cent of nicotine, were found to be of little or no value.

6. Hellebore was found to be absolutely ineffective against bedbugs.

7. Twenty miscellaneous powdered mixtures containing more than one active ingredient were tested and found to be more or less effective, depending on the amount of the active ingredients present.

8. Acetic acid, ammonia water, coal-tar oil (chlorinated), cottonseed oil, glycerol, kerosene, linseed oil, nicotine, oil of pine needles,—sabadilla seeds, turpentine and mercuric chlorid were found to be effective.

9. Twenty miscellaneous materials were found to be ineffective.

10. Sulphur fumigation, at the rate of 0.97 pound to 1,000 cubic feet of room space, was found to kill 100 per cent of the treated insects.

11. Three miscellaneous fumigants were found to be ineffective.

12. Phosphorus pastes proved to be of no value against bedbugs.

13. Kerosene was found to be effective, and gasoline and mercuric chlorid ineffective, against bedbug eggs.

COCKROACHES.

METHODS OF TESTING.

Two methods were employed in testing various materials against the common roach (*Blattella germanica* L.): (1) Badly infested rooms or kitchens were dusted or sprayed, and (2) cages were dusted or sprayed. The latter tests were made in wooden cages $11\frac{1}{2}$ inches long, $9\frac{1}{2}$ inches wide, and $2\frac{3}{4}$ inches deep, with top and bottom made of fine-mesh screen wire. For each test the entire interior of two or more of these cages was thoroughly dusted or sprayed with the substance to be tested. Twenty roaches, together with a small amount of bread for food and a few paper scraps to furnish hiding-places, were then added. At least two untreated cages, each containing 20 roaches with food and paper scraps, were used as a check with each set of tests. If the check showed a mortality of more than 20 per cent at the close of any series of tests, the experiment was discarded. However, it was rarely necessary to discard tests on this account, since the mortality of roaches confined in cages is almost negligible. Records were taken at the end of 24 hours, and as often afterwards as was considered necessary. The tests generally were closed at the end of one week, but in some cases observations were continued for longer periods.

It is considered that this method of testing, i. e., dusting or spraying the cage before inclosing the roaches, approximates the conditions that are met with in treating rooms, where only a very small proportion of the insects can actually be hit with a spray or powder, and therefore it is assumed that the real value of a given substance is determined by the number killed through coming in contact with it after it has been applied, rather than by the number killed through direct application. These cage tests, of course, are open to the objection that they are much more severe on the roaches than are the conditions which obtained in the room tests, since every part of the cage can be thoroughly treated, while many parts of a room will not be thoroughly sprayed or powdered, and many of the insects may not come in contact with the substance applied.

A limited number of fumigation tests were made in rooms or boxes. For the purpose of closely comparing the rapidity of the killing properties of two or more powders, tests were made by dipping the insects into the powder and placing them in empty vials where the effect of the substance could be noted.

ACTION OF MATERIALS ON ROACHES.

Upon careful study of the habits of roaches it has been found that these insects frequently cleanse their legs and antennæ. When any dirt or powder comes in contact with the appendages, these are at once drawn through the mouth parts of the insects and in this way cleaned. As a result, a certain amount of any powdered substance applied directly to a roach, or through which it may crawl, is thus taken into the mouth. In this way any poison, whether distasteful or not, finds its way into the stomach. Therefore it is not necessary to mix a stomach poison, in powdered form, with an attractive bait, since the chances are much greater that the poison will reach the stomach of the roach through its habit of cleansing itself than through the eating of the poisoned bait.

True contact poisons, as, for example, mineral-oil sprays, kill by coming in contact with the body. This may result (1) through direct application or (2) by coming in contact with the roach after it has been applied.

Certain substances, such as sodium fluorid, will act both as contact and as stomach poisons.

Substances also may kill through gases given off, as in the fumigation tests.

KILLING EFFECT OF POWDERED SUBSTANCES USED AS DUSTS AGAINST ROACHES.

SODIUM FLUORID.

In Table II are given the results of tests with sodium fluorid in kitchens and lunch rooms.

TABLE II.—*Results of tests with sodium fluorid against roaches in badly infested kitchens, bakeries, lunchrooms, milk-bottle exchanges, etc.*

Test No.	Per cent sodium fluorid.	Other ingredients.	Number used.	Duration of test.	Per cent killed.
1	100	.....	Many.....	48 hours...	100
2	100	.....	do.....	do.....	100
3	100	.....	do.....	do.....	100
4	100	.....	do.....	do.....	100
5	50	Wheat flour, 50 per cent.....	do.....	do.....	100
6	50	do.....	do.....	5 days....	98
7	50	Ground flint, 50 per cent.....	do.....	24 hours...	100
8	50	do.....	do.....	48 hours...	95

As will be noted in Table II, sodium fluorid, when used undiluted in badly infested kitchens and lunchrooms, kills practically every roach within 48 hours, and there is almost no reduction of this efficiency when it is used with equal parts of some inert substance, as flour or ground flint. The substitution of ground flint for wheat

flour did not decrease the effectiveness of sodium fluorid, and it is apparent also that the addition of a bait for the purpose of tempting the roach to eat the poison is not necessary. The insects are killed just as quickly through taking the fluorid into the system while cleansing the appendages as though eating poisoned bait.

In addition to the foregoing room tests, many cage tests were made in which sodium fluorid was mixed with lime or some other inert substance in varying proportions, ranging from 1 to 100 per cent. Under these conditions it was found that a mixture containing as low as 18 per cent of sodium fluorid killed all of the insects within 24 hours. Such low percentages as 5, 3, and 1 per cent were effective, but failed to kill 100 per cent, even when the tests were continued for 7 days.

Sodium fluorid proved the most effective of all the materials tested. While it acts primarily as a stomach poison, it may act also as a contact poison to a slight degree.

PYRETHRUM POWDER.

In tests of 22 different samples of pyrethrum powder (powdered flowerheads of *P. cinerariaefolium* and *P. roseum*) all were found to be very effective against roaches treated in cages, and no practical difference in value was found between the powders made from open, half-open, and closed flowers, or between the wild and cultivated flowers. Tests made during the winter of 1912 with pyrethrum powder from the crops of 1908, 1909, and 1910 showed no practical difference in their efficiency, thus indicating that this powder does not deteriorate materially in four years.

Pyrethrum stems, ground, were found to have no insecticidal value, and their addition to pyrethrum powder is certain to reduce its effectiveness.

The general effect of pyrethrum powder on roaches is to paralyze them and render them inactive almost at once, and, although slight movements of the legs and antennæ may continue for as long as 48 hours, a roach that has been thoroughly dusted will not recover.

Pyrethrum powder is not nearly as active against roaches as is sodium fluorid. Sodium fluorid may be diluted greatly and yet kill quickly, whereas pyrethrum powder when mixed with only a small percentage of inert matter kills very slowly. Therefore, in practice, it appears necessary to use unadulterated pyrethrum powder for effective results.

BORAX.

Borax, when used under average room conditions, was found to be partially effective, but can not be relied upon in cases of gross infestation.

Under the severe conditions attending the cage tests borax killed all of the treated roaches in from 4 to 7 days, when the amount of borax was not less than 12 per cent. With 10 per cent of borax or less, all were not killed in 7 days.

Borax as an insecticide acts very slowly, and satisfactory results against roaches, in most cases, can be obtained only when the material is repeatedly and persistently used.

Tests were made also to determine whether borax acts against roaches as a stomach poison or as a contact poison. In two tests bread which had been soaked in a saturated solution of borax was allowed to dry, and was then placed in the regular roach cages in large pieces, no other food being added. In the first of these tests all of the insects were dead at the end of 11 days, and in the other 70 per cent were killed in 16 days. In another test a mixture of 50 per cent borax and 50 per cent corn meal was moistened and allowed to dry in firm cakes, which were placed in the roach cage. In this test 75 per cent were killed in 16 days. In the untreated cages only 5 per cent were dead at the close of the experiment. Since, in these tests, there was very little opportunity for the borax to affect the roaches, except when taken internally with food, it would appear that the action of borax is primarily that of a stomach poison. This view is strengthened by the fact that borax was found to be ineffective against 8 species of sucking insects and effective against 7 species of chewing insects.

TOBACCO POWDERS.

In tests with nine different tobacco powders, in which the nicotine content ranged from 0.025 to 5.26 per cent, it was found that they were of no value against roaches. While nicotine is a stomach poison, it is evident that the roaches did not get enough of the powder, which carries only a small percentage of nicotine, to cause death.

PLASTER OF PARIS AND FLOUR.

Thorough tests were made of the method of killing roaches that has been quoted so often, namely, feeding the roaches a mixture of plaster of Paris and flour and furnishing them water to drink. The supposed effectiveness of this method is based upon the theory that the roach eats the mixture and then drinks the water, the plaster of Paris "setting" in the intestines and killing the roach.

A mixture of 25 per cent plaster of Paris and 75 per cent flour was fed to about 100 roaches on a table surrounded by a trough of water, the water being accessible to the roaches. Observations for nine days showed that none had been killed. This mixture was re-

placed with a mixture of 50 per cent plaster of Paris and 50 per cent flour, the roaches being allowed to remain on the table. Observations for 30 days showed that none had been killed, and they appeared as lively and healthy as when placed on the table. The presence on the table of innumerable roach droppings in the form of elongated white pellets of hardened plaster of Paris is conclusive evidence that the mixture was freely eaten, but that the plaster of Paris did not "set" until after it had left the intestines.

These tests demonstrate that the "plaster of Paris and flour treatment" is of no value against the common roach or "Croton bug," and would throw grave doubts upon its effectiveness against any other species of roaches.

MISCELLANEOUS POWDERS PARTIALLY EFFECTIVE AGAINST COCKROACHES.

Table III gives the results of tests with miscellaneous powders.

TABLE III.—*Results of tests with miscellaneous materials which were found to be effective against roaches.*

Test No.	Active ingredients.	Inert ingredients.	Kind of test.	Number used.	Duration of test.	Per cent killed.
					<i>Days.</i>	
1	Alum, 100 per cent.....	.....	Cage....	80	7	60-80
2	Arsenious oxid, 8.98 per cent....	Sodium oxid and paper.	..do....	40	7	60-80
3	Arsenious oxid, 61.01 per cent....	Sucrose, 35.28 per cent.	..do....	15	7	100
4	Arsenious oxid, 86.93 per cent....	Talc, 13.07 per cent..	..do....	40	4-7	95-100
5	Arsenious oxid, 76.14 per cent, and barium carbonate, 22.89 per cent, mixture.	.....	..do....	15	3	100
6	Barium carbonate, 100 per cent....	..do....	..do....	40	3	100
7	Barium fluorid, 100 per cent.....	..do....	..do....	40	10-14	100
8	Do.....	..do....	Room.	Many.	14	98-100
9	Boric acid.....	..do....	..do....	Many.	7	50-60
10	Calcium fluorid, 100 per cent.....	..do....	Cage....	20	7	95
11	Do.....	..do....	Room.	Many.	14	95
12	Copper sulphate, 100 per cent....	..do....	Cage....	40	8	80-90
13	Hellebore (<i>Veratrum</i> sp.), 100 per cent.	..do....	..do....	120	7-14	85-100
14	Mercury bichlorid, 1.09 per cent..	Ethyl and methyl alcohol.	..do....	140	7	30-65
15	Mercury bichlorid, 100 per cent....	..do....	..do....	20	1	100
16	Mercury bichlorid, 5.72 per cent, and phenol, 1.44 per cent, mixture.	Water.....	..do....	40	8-14	100
17	Paradichlorobenzene, 100 percent.	..do....	..do....	40	2-7	100
18	Do.....	..do....	Room.	40	2	48
19	Sabadilla seeds, powdered, 10 per cent.	Corn meal, 90 per cent.	Cage....	80	19-34	70-100
20	Sodium silicofluorid, 100 per cent.	..do....	..do....	100	5-7	75-100
21	Do.....	..do....	Room.	Many.	14	67

¹Fumigation.

²Furnished as food.

All of the materials given in Table III were active in varying degrees, killing from 48 to 100 per cent.

Although it would appear that several of these materials were satisfactorily effective, the fact that in the cage tests, in most cases, they required from 4 to 14 days to kill all of the treated roaches in

a given cage, shows that they act too slowly to commend themselves for general use. Barium carbonate and mercuric chlorid are the only materials that would appear to warrant further tests, and there is no indication that they will approach the effectiveness of sodium fluorid.

As only one of these mixtures (test No. 3) contained any substance that might serve as a bait, it is evident that their efficiency must be due to their being taken into the mouth by the roach when the appendages are cleaned. This conclusion is strengthened by the results of dipping tests, where roaches dipped in arsenic trioxid or sodium arsenite died in less than 48 hours.

It should be emphasized that arsenious oxid and mercury bichlorid are far too poisonous to human beings to be generally used as roach remedies under average dwelling conditions.

Hellebore, while poisonous to insects when taken internally, acts so very slowly that it can not be classed as a roach remedy.

In the test of paradichlorobenzene $8\frac{1}{2}$ pounds of this material were exposed for 44 hours at a temperature of about 80° F. in a room the capacity of which was 846.5 cubic feet. The roaches were placed on the floor in two cages, and even this heavy fumigation, with the insects fully exposed, failed to kill 50 per cent.

MISCELLANEOUS POWDERS INEFFECTIVE.

The following list of various powdered materials tested, unadulterated, was found to be ineffective against roaches. Not less than 40 roaches were used in the cage tests, and the experiments were continued for at least a week. The room tests were made in badly infested rooms or kitchens and were generally continued for seven days. The method of testing is indicated in parentheses after the name of the material.

Miscellaneous powders ineffective against cockroaches.

Allspice (cage).	Colocynth pulp (cage and room).
Angelica root (cage).	Cornstarch (room).
Anise seed (cage).	Corn meal (room).
Barium sulphate (cage).	Dolomitic lime (cage).
Calcium carbonate (cage and room).	Eucalyptus leaves (cage).
Calcium hydroxid (room).	Ferric oxid (room).
Calcium oxid (cage and room).	Ferrous oxid (room).
Calcium sulphate (cage and room).	Flint, ground (cage).
Camphor (cage and room).	Fuller's earth (room).
Cassia (cage).	Gypsum (cage and room).
Chamomile flowers (cage).	Lead carbonate (cage and room).
Charcoal (room).	Lime, air-slaked (cage and room).
Cloves (cage).	Magnesium carbonate (room).

Miscellaneous powders ineffective against cockroaches—Continued.

Magnesium oxid (room).	Silica (room).
Pepper, cayenne (cage).	Sodium bicarbonate (cage and room).
Potato starch (room).	Sodium carbonate (cage and room).
Quassia (cage and room).	Sulphur, refined (room).
Road dust (cage and room).	Sulphur sublimated (cage and room).
Rosin (cage).	Wheat flour (room).

EXPERIMENTS WITH LIQUIDS AND PASTES.**KILLING EFFECT OF PHOSPHORUS PASTES.**

Ten phosphorus pastes (proprietary), ranging from 0.14 per cent to 2.33 per cent, were tested against roaches in cages, but none of them proved effective. Several of them did kill from 50 to 90 per cent, but since, in most cases, the tests were continued for at least seven days, and in no case were all roaches killed in this time, it can be seen that these pastes, even under the most severe conditions and when no other food was available, were not effective to the extent that would be considered satisfactory.

In addition to the cage tests, two of the pastes were tested in badly infested kitchens, and were still less effective. A few dead roaches were found in the kitchens 24 hours after the application of the pastes, but in no case did it appear that more than 10 per cent had been killed, nor was the infestation greatly reduced. The pastes used in the kitchen tests, however, contained only 1.01 per cent and 1.34 per cent of phosphorus.

Under certain conditions, where all food can be kept from the roaches for several days and the phosphorus paste used liberally, it may give satisfaction. The senior writer observed the use of phosphorus paste against roaches, which, in the absence of other food, fed on certain of the young, tender plants in a greenhouse of the War Department. Two or three roaches were seen eating the paste, and the manager of the greenhouse claimed to get entirely satisfactory results from the use of this substance against this insect. This material, however, can not be relied upon for general use under average conditions.

HYDROCARBON OILS.

Numerous hydrocarbon-oil preparations, consisting essentially of oils of the nature of gasoline or kerosene, or some heavier oil, to which, in certain cases, had been added small amounts of nitrobenzene or phenols, were tested against roaches in cages. All of these sprays were found to be effective.

In considering the effectiveness of these oil sprays, due weight must be given to the fact that in cage tests the roaches are placed in the

sprayed cages before the oil has dried and that they are obliged to remain on, or near, surfaces that are well wet with the oil. Under room conditions many of the insects are hiding in cracks and crevices, and often escape being hit by the oil at the time of application. If they remain in hiding until the oil has dried, which may be from one to several hours, they escape death, but those venturing out before the oil has dried are killed by contact with it. Owing to the chance that many may escape contact with the oil, such sprays, while effective, are less satisfactory than sodium fluorid.

The addition of nitrobenzene or phenols does not appear to increase the effectiveness of the mineral oil.

COAL-TAR CREOSOTE EMULSIONS.

Tests were made with many coal-tar creosote emulsion preparations, undiluted, and in dilutions ranging from 1 part of the emulsion in 10 parts of water to 1 part of the emulsion in 100 parts of water. When applied undiluted the emulsion killed all of the roaches within 24 hours, but as the dilution was increased the effectiveness decreased rapidly, so that when the dilution was greater than 1 part emulsion to 20 parts of water the material proved only slightly effective, or ineffective.

Both cage and kitchen tests indicate that such emulsions should not be diluted more than 1 part in from 20 to 25 parts of water.

FUMIGATION AGAINST ROACHES.

SULPHUR.

Five tests were made with sulphur as a fumigant, the dosage ranging from 4 ounces to 55 ounces per 1,000 cubic feet. The number of tests was so small that no definite conclusions as to the effective strength are drawn. The tests showed, however, that roaches can be killed by sulphur fumigation, and indicate that the minimum amount of sulphur to be used for 1,000 cubic feet (10' by 10' by 10') is about 9 ounces.

NICOTINE.

Nicotine, when used as a fumigant, was found to be of no value against roaches. A dosage of as much as 8 ounces of tobacco extract (40 per cent nicotine, as sulphate) to 1,000 cubic feet failed to kill them. A much greater strength than this would probably be effective, but the cost would be prohibitive.

SUMMARY.

1. Sodium fluorid was found to be the most rapid killer of roaches of all the substances tested. Only 24 hours were required to kill 100 per cent in cage tests, even when the material was diluted down to

18 per cent content. Practically 100 per cent were killed in treated kitchens by the use of a mixture containing 50 per cent of sodium fluorid.

2. Pyrethrum powder, pure, killed practically all of the roaches within 48 hours in cage tests. Its effectiveness was greatly reduced when slightly diluted.

3. Borax, unadulterated, and in combination with inert matter wherein there was less than 12 per cent borax, required from three to seven days to kill all of the roaches in cage tests, proving it to be very slow. Borax, used alone, was only partially effective in kitchen tests.

4. Phosphorus pastes were partially effective in cage tests and only slightly effective in room tests.

5. The various hydrocarbon-oil sprays, undiluted, killed from 80 to 100 per cent in treated cages.

6. Coal-tar creosote emulsions, undiluted, killed all in cage tests, but their effectiveness fell very rapidly when even slightly diluted with water.

7. Tobacco powders containing as high as 5.26 per cent of nicotine were found to be ineffective in cage tests.

8. The plaster of Paris and flour mixture was ineffective against roaches.

9. Alum, arsenious oxid, barium carbonate, barium fluorid, boracic acid, calcium fluorid, copper sulphate, hellebore, mercury bichlorid, paradichlorobenzene, sabadilla seeds, and sodium silicofluorid were found to be more or less active against roaches.

10. Thirty-eight miscellaneous materials were found to be ineffective.

11. Sulphur fumigation, at the rate of 9 ounces of sulphur to 1,000 cubic feet, was effective.

12. Nicotine fumigation, at the rate of 8 ounces of tobacco extract (40 per cent nicotine, as sulphate) to 1,000 cubic feet, was ineffective.

CLOTHES MOTHS.

SPECIES USED IN EXPERIMENTS.

There are two important species of clothes moths occurring in the United States, the webbing or southern clothes moth (*Tineola biselliella* Hum.) and the case-making clothes moth (*Tinea pellionella* L.). The former species was used exclusively in the experimental work on account of its abundance in Washington, D. C., its larger size, and the fact that it readily leaves its case when disturbed.

METHODS OF TESTING.

Against the adults.—Many cage tests were made against the adults in the laboratory, as follows: Twenty large, well-ventilated cages

were maintained, allowing 20 separate tests to be carried on at one time. Each cage was made of tulip, or what is commercially known as "whitewood," which, on account of its almost complete lack of odor and volatile oils, should be unobjectionable to moths. The inside dimensions of the cages were: Length, 3 feet; width, $2\frac{1}{2}$ feet; depth, 10 inches. In the top a door, 3 feet by $1\frac{1}{2}$ feet, covered with fine-mesh copper wire, provided means of entrance and ventilation, and at the back and at one side were screened apertures as further means of ventilation.

In each cage at the beginning of a test were placed three whitewood boxes, each 10 by 10 by 8 inches, fitted with sliding covers. A quantity of all-wool flannel, in pieces about 6 by 12 inches, was placed in each box. Flannel in two boxes was treated with the material being tested, while that in the third box was untreated and served as a check. The boxes containing the treated flannel were kept on one side of the cage; the untreated box on the other side, in order to minimize any chance of odors from the treated flannel affecting the untreated. The sliding covers were about three-fourths closed to exclude light and, at the same time, leave ample room for entrance of moths.

Finally, from 10 to 20 adult moths were placed in the large cage, the door quickly fastened, and the whole left in a quiet room. After a week or so more moths were often added to the cage, depending upon the available supply. The cage was fairly light; boxes fairly dark; and, as moths have a decided aversion to light, this condition tended to attract them to the boxes. The tests ran at least a month, sometimes longer, the purpose being to secure a maximum number of eggs hatched into larvæ large enough to be accurately counted. At the time results were recorded the number of dead moths, of living and dead larvæ, and of unhatched eggs was noted. The number of live larvæ found on the treated flannel, compared with the number found on the untreated flannel used as a check, determined the protective¹ value of the substance against moth infestation.

In addition to the cage tests, several room and trunk tests were made against the adults to approach more nearly practical conditions.

Against the larvæ.—The substance being tested was applied to the infested flannel in trunks, boxes, open battery jars, and closed bat-

¹ The word "protective," used in connection with these tests, is a rather broad term and is purposely used as such. At the time of testing the object was to determine whether materials used against moths as "repellents" had any so-called "repellent" effect upon the adult moth. Observations showed that, in the majority of cases where the effective remedies were used, adults were found to have entered boxes containing treated flannel, and often the number of dead ones there present, at the time of examination, equaled the number dead in boxes containing untreated flannel. It would appear, then, that the substances used did not act as repellents, but that moths entered boxes containing treated flannel and were either killed by the fumes or remained there until death occurred from other causes.

tery jars. Two lots of larvæ, treated, and one lot, untreated, made up each test. The usual duration of each test was one week, it being assumed that if the material used did not kill in that time it would be of no practical value.

Against the eggs.—Large pieces of flannel were placed in a jar containing many adult moths, and when the moths had deposited numerous eggs on the flannel it was taken out and cut into pieces in such a manner that each piece contained 10 or more eggs. The material to be tested was thoroughly applied to the pieces of flannel containing the eggs, and the treated flannel was then placed in open jars. An untreated lot, serving as a check, was used in each test. Observations were made at the end of 10 days to 2 weeks.

EXPERIMENTS AGAINST CLOTHES MOTHS.

NAPHTHALENE: EFFECT ON CLOTHES-MOTH ADULTS.

In two cage tests, as described, the flannel in the treated boxes was dusted with naphthalene flakes, and 10 adult moths were liberated in each cage. Examination made four weeks after treatment showed that the flannel in the treated boxes was entirely free from infestation by clothes-moth larvæ, whereas the flannel in the untreated boxes was badly infested. Two other cage tests were made, in which naphthalene in the form of cakes or "bricks" was used, with the same result.

A room approximating 1,000 cubic feet was used for a "protective test" with naphthalene on a large scale. Three of the above-described small whitewood boxes containing flannel were placed in opposite corners of the room. About one-half pound of naphthalene flakes was placed in box No. 1; about one-fourth pound of naphthalene flakes in box No. 2; and one-fourth pound of naphthalene balls in box No. 3. Two boxes containing untreated flannel were used as checks. One hundred and forty adult moths were liberated in the room, which was made sufficiently tight to prevent their escape. At the end of 2½ months all of the treated boxes were entirely free from infestation, while the untreated boxes contained many living larvæ.

A duplicate room test was made, one lot of treated flannel being placed in a closet in the room, and the closet door being allowed to remain open. Again, all treated flannel remained free from infestation, while on the untreated flannel 80 live larvæ were counted.

Several trunk tests were made. In the first series flannel, to which was added naphthalene flakes at the rate of one-fourth pound to 5 cubic feet, was placed in a trunk of average size. Forty adult moths were liberated in the trunk, and the lid closed. Examination at the end of eight weeks disclosed no larvæ on the flannel, and all of the adults dead. In an untreated trunk serving as a check, in which the

same number of adults were liberated, the flannel was badly eaten by larvæ, and a large number of live larvæ were present. In a duplicate test, in which naphthalene balls were used at about the same rate, the results were identical.

A second series of trunk tests was made, in which three trunks of average size were used, and adult moths were liberated in the trunks from time to time during the course of the experiments. In trunk No. 1 three-fourths pound of naphthalene flakes was scattered over the flannel and over the bottom of the trunk. Ten moths were added every two weeks, from May 7 to July 21, making a total of 70 moths used. Two months later (Sept. 20) examination developed that the flannel was unhurt, and no living adults, no larvæ, or eggs were found. In trunk No. 2 one pound of naphthalene balls was used, and moths were added as in trunk No. 1. The results were the same as obtained with the flake naphthalene. In the check (untreated) trunk the flannel was badly eaten at the close of the experiment, hundreds of live larvæ and 7 live adults being present.

To determine the rapidity with which adults are killed by confined fumes of naphthalene, a third series of trunk tests was conducted. Ten moths were placed in each of three tight trunks containing flannel and in each case a reasonable amount of naphthalene flakes was added. In from two to six days, all of the moths were dead.

NAPHTHALENE: EFFECT ON CLOTHES-MOTH LARVÆ.

Battery jars and trunks were used to test the effect of naphthalene on the larvæ. In the battery-jar tests jars of 216 cubic-inch content were used. From 10 to 20 larvæ, one-half to three-fourths grown, were placed upon a piece of all-wool flannel in each jar, and a liberal amount of naphthalene was applied to the entire piece of flannel. Two lots of larvæ, treated, and one lot, untreated, made up each test. The forms of naphthalene so tested were (1) one test of coarse flakes, (2) four tests of fine flakes, (3) one test of balls, and (4) one test of cake or brick. In each test the jars remained open. At the end of 7 days each of these substances was found to have killed from 85 to 100 per cent of the larvæ, and of the few remaining alive some were inactive. The flannel, in all cases, was undamaged.

In a second series of jar tests 10 half-grown larvæ were placed on flannel in each of five battery jars, which were tightly covered with heavy paper. To the 5 jars naphthalene flakes were added at the rate of 2, 4, 8, 20, and 40 grams, respectively, per cubic foot. At the end of one week the 2 and 4 gram applications had killed 90 per cent, and in every case all larvæ had been killed by the heavier dosages. In the untreated jars, serving as checks, only 5 per cent of the larvæ were dead. From observations on the effect of naphthalene on the

larvæ in these jar tests it was concluded that the naphthalene killed much more effectively and rapidly when the fumes were confined by covering the jars.

In trunk tests against larvæ fresh flannel and 25 larvæ, half-grown, were placed in a lantern globe, the two ends of which were covered with cheesecloth. This lantern globe was placed in a trunk of average size, in which naphthalene flakes at the rate of one-fourth pound to 5 cubic feet were sprinkled, and the lid closed. The use of the lantern globe was to prevent the naphthalene from coming in contact with the larvæ, so that any action noted on the larvæ would be from the effects of the fumes. Examination at the end of 32 days showed that all the larvæ were dead. The flannel was found to be very slightly eaten, showing that some of the larger larvæ had, no doubt, survived long enough to feed slightly. A duplicate test was made, in which naphthalene balls were used at about the same rate, with identical results. In an untreated trunk, serving as a check, to which the same number of larvæ had been added, were found many adult moths and more than a hundred larvæ, and the flannel was badly eaten.

The results of these tests indicate that the killing effect of the naphthalene is due principally to the fumes.

A second series of trunk tests was made, using three trunks of average size, in which larvæ were added at intervals during the course of the experiment. In trunk No. 1 three-fourths pound of naphthalene flakes was scattered over the flannel and the bottom of the trunk. Ten larvæ, half to full grown, were added every 2 weeks for 10 weeks, making a total of 50 larvæ used. Two months after the last lot of larvæ was added examination showed that none had pupated, there had been only very slight feeding on the flannel, and all had been killed.

In trunk No. 2 one pound of naphthalene balls was used, and larvæ were added from time to time as in the test with trunk No. 1. The results were the same as those obtained in the use of naphthalene flakes, except that there was no feeding on the flannel, which was due, no doubt, to the fact that a larger quantity of balls than flakes was used.

In the check trunk (trunk No. 3), at the close of the experiment, numerous moths and larvæ were found and the flannel was badly eaten.

NAPHTHALENE: EFFECT ON CLOTHES-MOTH EGGS.

Pieces of flannel about 1 inch square, containing 10 or more clothes-moth eggs, were thoroughly dusted with naphthalene flakes and placed in two open battery jars. Observations made 10 days later

showed that none of the eggs had hatched, while in an untreated jar 16 young larvæ and 2 unhatched eggs were found.

In a duplicate test, in which naphthalene balls were placed on the flannel, the results were identical.

From the results of the foregoing experiments it will be seen that naphthalene kills all stages of the clothes moth very effectively.

CAMPHOR.

Effect on clothes-moth adults.—Gum camphor, broken into small pieces, was used at the rate of about 5 ounces to 5 cubic feet, in a trunk containing flannel. Thirty moths were liberated in the trunk, and the lid closed. Examination made 32 days later showed no living adults and no larvæ, and the flannel had not been fed upon. Cage tests with this substance showed a variation in efficacy from 65 to 100 per cent as compared with the untreated flannel.

Effect on larvæ.—Twenty-five half-grown larvæ were placed on clean flannel in a trunk, and gum camphor was added at the rate of about 5 ounces to 5 cubic feet and the lid closed. Thirty-two days after treatment all of the larvæ were found to be dead, and the flannel had been slightly damaged from feeding.

Gum camphor scattered on infested flannel in an open jar killed 60 to 67 per cent of the larvæ in about 7 days.

Effect on eggs.—In two tests in open battery jars gum camphor killed all of the eggs, when sprinkled on pieces of flannel containing 10 or more eggs.

While camphor proved effective in varying degrees against the various stages of the clothes moth, close observations made during the course of the experiments show that it is much less active than the different forms of naphthalene.

RED-CEDAR CHEST.

Effect on clothes-moth adults.—A red-cedar chest of 10 cubic feet capacity was utilized. No record of the date of manufacture of the chest could be obtained. On May 6, 1915, 10 adult moths and a supply of flannel were placed in the chest. Ten more moths were added every two weeks until a total of 70 was reached. Two months after the last moths were added examination showed that all had been killed and that no eggs or larvæ were present.

Two years later (1917) 30 moths and a supply of flannel were added to the same chest. Observations made nine weeks after the experiment was started revealed no living adults, no eggs, and no larvæ. In a trunk, serving as a check, to which the same number of adults were added at the same time, more than 50 live larvæ were counted on the flannel at the close of the experiment.

Effect on larvæ.—The cedar chest above described was used also for a test against larvæ. In 1915 flannel was placed in this chest, and 10 one-half to three-fourths grown larvæ were added every two weeks until a total of 60 was reached. Examination made two months after the last addition of larvæ showed seven live larvæ; 36 larvæ had died and 17 had pupated. Of the 17 pupæ 2 died in the pupa stage and 15 emerged as moths, but died before any eggs were laid. The flannel had been fed upon considerably, but was not badly eaten.

Two years later (1917) this experiment was duplicated by adding 25 one-half to three-fourths grown larvæ at one time and allowing the experiment to run 33 days. The results were almost identical with those of the first experiment.

Effect on eggs.—A small piece of flannel containing many clothes-moth eggs was placed in the cedar chest described above. At the end of 23 days practically all of the eggs had hatched, but all of the resulting larvæ died almost immediately. A duplicate test was made, with identical results. The check flannel placed in a battery jar showed many eggs hatched and all larvæ alive.

The results of the foregoing tests indicate that adult clothes moths and young clothes-moth larvæ are killed when placed in a cedar chest, but that the larvæ one-half to full grown may live for a considerable length of time, and even, in some cases, reach the pupa stage and emerge as moths. It was observed in all tests that very little feeding was done.

RED CEDAR SHAVINGS AND CHIPS.

Effect of red-cedar shavings and chips on clothes-moth adults, larvæ, and eggs.—In cage tests cedar shavings and chips did not entirely prevent the moths from laying eggs on the treated flannel, yet they showed an apparent protective power when the treated flannel was compared with the untreated.

When cedar shavings and chips were thoroughly applied to larvæ more than one-fourth grown, they had no killing effect, but were somewhat effective against very young larvæ. Cedar chips burned in a fumigating box, at the rate of $2\frac{1}{2}$ grams to 13 cubic feet, were not effective against larvæ.

Cedar chips proved ineffective in preventing the hatching of eggs.

Red-cedar leaves were entirely ineffective in killing larvæ and preventing moth infestation. The oil of cedar leaves, however, proved very effective for both purposes.

In addition to the above forms of cedar, very small boxes having an approximate content of 432 cubic inches ($\frac{1}{4}$ cubic foot), made of freshly cut red-cedar lumber, were used for certain tests. Adult

moths were killed in from three to four days when confined in these boxes. From 18 to 25 days were required to kill 85 to 90 per cent of the half-grown larvæ when placed in the boxes.

PARADICHLOROBENZENE.

Effect on clothes-moth adults and larvæ.—Paradichlorobenzene killed only 30 per cent of the adult moths and none of the larvæ placed in a room of 846 cubic feet capacity. Eight and one-half pounds of paradichlorobenzene was exposed in 6 dishes for 21 hours, and during this time one-half pound of the material evaporated. A liberal amount of paradichlorobenzene scattered on infested flannel in an open jar killed all of the exposed larvæ in 20 hours.

In boxes, trunks, or closets this substance would, no doubt, be very effective, when used liberally, as indicated by its rapid killing effect against clothes-moth larvæ when confined in a small space; but owing to rapid evaporation its effectiveness would not last nearly as long as that of naphthalene.

PYRETHRUM POWDER.

Effect on clothes-moth larvæ and eggs.—Pyrethrum powder was found to kill 100 per cent of larvæ on infested flannel, even when used in proportions as low as 4 parts of pyrethrum powder to 96 parts of flour.

Two tests were made with pyrethrum powder against clothes-moth eggs. Whether or not the eggs were prevented from hatching has not been determined definitely. If any hatched, however, the resulting larvæ died immediately, since 16 days after treatment no larvæ were found and the flannel was not damaged.

While no test with pyrethrum powder was made against adult clothes moths, it is safe to say that the powder would kill the adults. Clothing thoroughly dusted with pyrethrum powder would be protected from larvæ resulting from any eggs that might be present.

HYDROCARBON OILS AND OIL EMULSIONS.

Effect on clothes-moth adults.—Various oils of the nature of kerosene have proved very effective in preventing infestation of larvæ, resulting from moths liberated in cages, as described on pages 16 and 17. However, flannels treated with oil emulsions at dilutions varying from 1 part of emulsion in 65 parts of water to 1 part of emulsion in 250 parts of water were not protected from infestation. It is necessary to use such emulsions either undiluted or only slightly diluted if satisfactory control is to be expected.

The vapors evolved from kerosene in a closed jar killed adult moths in 2½ hours, the experiment being so arranged that the moths were not in contact with the oil.

Commercial crude carbolic acid, used at the rate of 1 part of the acid to 10 parts of water, proved effective in protecting flannel from moth infestation.

Effect on larvæ.—Experiments with three different oils of the nature of kerosene, and one experiment with gasoline sprayed on pieces of flannel infested with larvæ, resulted in the killing of all larvæ in each case. Oil emulsions proved of little value, when diluted as much as 1 part of the emulsion to 65 parts of water, against larvæ, as well as against adults. Oil emulsions should be used either undiluted or only slightly diluted.

Commercial crude carbolic acid, used at the rate of 1 part of the acid to 10 parts of water, killed 85 per cent of the larvæ on badly infested flannel.

The vapors evolved by kerosene in a closed jar killed larvæ in $4\frac{1}{2}$ hours, the experiment being so arranged that the larvæ were not in contact with the oil.

Effect on eggs.—Two pieces of flannel, each containing 10 or more clothes-moth eggs, were sprayed with gasoline, with the result that all of the eggs were killed. Also, 3 and 5 per cent solutions of commercial crude carbolic acid killed all eggs in similar tests.

SOAP.

Effect on clothes-moth larvæ.—Fish-oil soap, used at the rate of 1 pound of the soap to 12, 25, and 40 gallons of water, killed all of the larvæ when sprayed on infested flannel. Laundry soap in two tests, in which it was used at the rate of 1 pound to 10 gallons of water, killed all of the larvæ.

Effect on eggs.—Laundry soap was sprayed on eggs on flannel, the strengths used being 1 pound of soap to 10, 20, and 40 gallons of water. The strongest solution killed most of the eggs, but the two weaker solutions were entirely ineffective.

The above results with soap indicate that spraying or washing clothing with strong soap solution will free it from larvæ and eggs of the clothes moth.

NICOTINE EXTRACTS AND TOBACCO POWDER.

Effect on clothes-moth adults.—Flannel dusted with powdered tobacco leaves containing 4.56 per cent nicotine remained free from moth infestation in a single cage test, the untreated flannel, under the same conditions, becoming infested with 12 larvæ. Tobacco powders containing 0.4 per cent and 0.8 per cent of nicotine were not effective in preventing infestation in cage tests. Since the average tobacco powder found on the market contains a great deal less than

4 per cent of nicotine, this substance should not be depended upon for protection of clothing against moth attack.

No tests with nicotine extract were made to determine its value in protecting clothing from moth infestation in the presence of adults.

Effect on larvæ.—In Table IV are shown the results of 18 tests with several forms of nicotine in varying dilutions.

TABLE IV.—*Tests of the killing effect of nicotine solutions and tobacco powders against clothes-moth larvæ.*

Test No.	Nicotine, amount and form.	Dilution in water.	Treated.		Untreated.	
			Number of larvæ used.	Per cent dead.	Number of larvæ used.	Per cent dead.
1	13 per cent as extract.....	1 to 125.....	20	5	10	20
2	do.....	1 to 125.....	10	40	10	10
3	12 per cent as extract.....	1 to 32.....	20	20	10	20
4	do.....	1 to 32.....	20	10	10	10
5	do.....	1 to 32.....	20	5	10	40
6	40 per cent as sulphate.....	1 to 100.....	20	30	10	20
7	do.....	1 to 100.....	10	-----	10	10
8	do.....	1 to 75.....	20	15	10	20
9	do.....	1 to 75.....	10	20	10	30
10	do.....	1 to 50.....	20	30	10	30
11	do.....	1 to 50.....	10	30	10	20
12	do.....	1 to 25.....	10	50	10	40
13	do.....	1 to 25.....	20	55	10	30
14	0.41 per cent in tobacco dust.....	Undiluted.....	20	5	10	-----
15	0.8 per cent in powdered stalks.....	do.....	20	-----	56	6
16	3.14 per cent in powdered plant.....	do.....	20	-----	50	8
17	3.38 per cent in powdered leaves.....	do.....	20	10	10	-----
18	4.56 per cent in powdered leaves.....	do.....	20	20	50	6

¹ Of those dead, 25 per cent probably drowned, as water was found in the jar.

It is seen that every form of nicotine, at the dilutions used, failed to kill an appreciable number of larvæ, and since the greatest strength used was 1 part of tobacco extract (40 per cent nicotine, as sulphate) to 25 parts of water, it is apparent that to kill a higher percentage the preparation would have to be used very slightly diluted or undiluted. This evidently would not be practical on account of the comparative cost and the danger of staining woollens.

Effect on eggs.—A nicotine-water solution (40 per cent nicotine), used at the rates of 1 part of the mixture to 25 and to 50 parts of water, killed all of the eggs on sprayed flannel. When the proportion of water was increased to 75 parts, 2 eggs hatched in one test and none in the other. The two larvæ resulting from the hatched eggs died almost immediately. When a dilution of 1 to 100 was used in 2 tests, one egg hatched in one test and two in the other, the resulting larvæ dying almost immediately. No greater dilutions were used, but the results indicate that when used at a much greater dilution than 1 to 100, the material would not be effective against the eggs. Owing to the expense of such a substance its use would be prohibitive.

MISCELLANEOUS MATERIALS.

Effect on clothes-moth adults.—Lavender flowers, cayenne pepper, and allspice are of no value in preventing moth infestation.

Cloves and oil of lavender were effective in protecting flannel from moth infestation.

Effect on larvæ.—Miscellaneous substances found to be effective against larvæ are as follows:

Alcohol (ethyl), 95 per cent solution used as a spray. Cloves, used as a dust. Sodium fluorid, used as a dust.

Miscellaneous substances found to be ineffective against clothes-moth larvæ are as follows:

Allspice (dusted).	Lead carbonate (dusted).
Angelica root (dusted).	Lead oxide (dusted).
Borax (dusted).	Lime [air-slaked] (dusted).
Colocynth pulp (dusted).	Pyrethrum stems (dusted).
Eucalyptus leaves (dusted).	Quassia chips (dusted).
Formaldehyde (sprayed 1 to 10).	Sodium bicarbonate (dusted).
Hellebore, white (dusted).	Sodium carbonate (dusted).
Lavender flowers (scattered on).	

Effect on eggs.—Sulphur, salt, and borax were of no value in preventing hatching of clothes-moth eggs, when thoroughly sprinkled on infested flannel.

Formaldehyde killed the eggs when used undiluted and when diluted with 5 parts of water, but when used at the rate of 1 part to 10 parts of water eggs were not killed.

At 50 and at 70 per cent a solution of ethyl alcohol destroyed the viability of eggs, but at 30 per cent a solution was ineffective.

FUMIGANTS.

Effect on clothes-moth adults and larvæ.—In Table V are recorded the results of fumigation tests with miscellaneous materials.

TABLE V.—Results of fumigation tests with miscellaneous materials against adults and larvæ of the clothes moth. Tests made in a fumigating house containing 360 cubic feet of space.

Test No.	Name of material.	Amount.	Method of application.	Number used.		Percentage killed.	
				Adults.	Larvæ.	Adults.	Larvæ.
		Grams.					
1	Charcoal.....	265	Burned with forced draft		10		0
2	Formaldehyde.....	65	Evaporated over lamp..	10	10	0	0
3	Paraformaldehyde.....	23	do.....	20	20	0	0
4	do.....	65	do.....	20	20	30	5
5	Sulphur.....	208	Burned with wick.....	15	10	100	20
6	do.....	243	Burned in retort.....		10		100
7	Sulphur and carbon, equal parts.....	228	do.....	20	20	50	0

As will be noted, sulphur burned in the form of a candle, at the rate of 208 grams to 360 cubic feet, killed all adults in 18 hours. The combination of sulphur and carbon in equal parts, when burned at the rate of 228 grams to 360 cubic feet, killed 50 per cent of the adults in 18 hours. Sulphur fumes killed larvæ in house fumigation when used at the rate of 243 grams to 360 cubic feet, but was ineffective at weaker strengths.

Formaldehyde in solution and in crystalline form (paraformaldehyde) failed to kill a majority of the adults and was of no value against larvæ.

HEAT.

Effect on clothes-moth larvæ.—The effect of heat on larvæ was tested by placing the infested flannel in an incubator. Ten larvæ were used in each case, with the results shown in Table VI.

TABLE VI.—*Effect of heat on clothes-moth larvæ.*

Length of exposure.	Degree of heat.	Result.
<i>Minutes.</i>	<i>° F.</i>	
6	128	All killed.
11	120	Do.
31	110	Do.
11	110	30 per cent killed.
31	105	20 per cent killed.

A single test made by exposing a piece of flannel containing many larvæ in the sun for six hours, the developing temperature ranging from 80° F. to 105° F., resulted in the death of all larvæ.

Effect on eggs.—The effect of heat on clothes-moth eggs was tested in the same manner as described above for larvæ, 10 or more eggs being present on each piece of flannel. See Table VII.

TABLE VII.—*Effect of heat on clothes-moth eggs.*

Length of exposure.	Degree of heat.	Result.
<i>Minutes.</i>	<i>° F.</i>	
6	128	All killed.
6	125	Do.
11	120	Do.
31	110	Do.
11	110	None killed.
31	105	Do.

A single test made by exposing for six hours a piece of flannel containing many clothes-moth eggs to the sun in the same manner as described for larvæ resulted in the killing of the eggs. The temperature of the flannel during the exposure rose from 80° F. to 105° F.

HOT WATER.

Effect on clothes-moth larvæ and eggs.—Both larvæ and eggs of the clothes moth were killed by dipping infested flannel for 10 seconds in water at a temperature of 140° F. When dipped for the same length of time in water at a temperature of 122° F., however, neither the larvæ nor the eggs were killed.

SUMMARY.

1. Naphthalene was uniformly effective in protecting woolsens from clothes-moth infestation and in killing all stages of the insect.

2. Camphor, though more or less effective against all stages of the clothes moth, proved considerably less active than did naphthalene.

3. A red-cedar chest readily killed all adult moths and showed considerable killing effect upon young larvæ. It did not prevent the hatching of eggs, but killed all the resulting larvæ almost immediately.

4. Red-cedar chips and shavings, while not entirely effective in keeping the adult moths from laying eggs on the flannel treated, appeared to protect it from appreciable injury when used liberally. The chips and shavings showed practically no killing effect against eggs, or against the larvæ when over one-fourth grown.

5. Paradichlorobenzene was not effective against adults and larvæ in a room fumigation test of 21 hours duration, but killed larvæ effectively in battery-jar tests.

6. Pyrethrum powder readily killed clothes-moth larvæ.

7. Various mixtures of oils were effective in protecting clothing from infestation, when used undiluted or but slightly diluted, and killed 100 per cent of the larvæ when used undiluted.

8. Laundry soap killed both larvæ and eggs when used in strong solution.

9. Various tobacco extracts containing nicotine and tobacco powders, when used at reasonable strengths, proved of no value against this insect.

10. Lavender flowers, cayenne pepper, and allspice were ineffective and cloves and oil of lavender effective in protecting flannel from moth infestation.

11. Powdered cloves, sodium fluorid, and 95 per cent alcohol, undiluted, killed larvæ.

12. Allspice, angelica root, black pepper, borax, cayenne pepper, colocynth pulp, eucalyptus leaves, formaldehyde, hellebore, lead carbonate, lead oxid, lime, quassia chips, sodium bicarbonate, and sodium carbonate were of no value in killing clothes-moth larvæ.

13. Borax, salt, and sulphur did not kill clothes-moth eggs; 50 per cent and 70 per cent solutions of ethyl alcohol and a 16 per cent solution of formaldehyde killed the eggs.

14. Fumigation with sulphur proved effective in killing both adults and larvæ.

15. Heat killed both larvæ and eggs when they were exposed in an oven for 31 minutes at 110° F., and in less time at higher temperatures.

16. Hot water killed both larvæ and eggs when infested flannel was dipped for 10 seconds in water at a temperature of 140° F.

CARPET BEETLES.

SPECIES USED IN EXPERIMENTS.

There are two well-known species of carpet beetles in the United States, both injurious to woolen fabrics, but, in contrast to the clothes moths, generally attacking the heavier fabrics, such as carpets and blankets. One species is known as the "carpet beetle" or "black carpet beetle" (*Attagenus piceus* Oliv.) and the other as the "carpet beetle" or "buffalo bug" (*Anthrenus scrophulariæ* L.). The former species, on account of its greater abundance in Washington, D. C., was used in the experimental work.

METHODS OF TESTING.

The methods used in testing the insecticide materials against the carpet beetle were essentially the same as used in the clothes-moth tests described on pages 16 and 18.

EXPERIMENTS AGAINST CARPET BEETLES.

NAPHTHALENE.

Effect on carpet-beetle adults.—Two cage tests with naphthalene flakes and two with naphthalene balls, 30 adult beetles being used in each test, resulted in complete protection of the treated flannel in all cases, while the untreated flannel was infested with from 5 to 13 living larvæ.

Two trunks containing flannel were used in tests against the adult beetles. In one trunk naphthalene flakes were applied at the rate of one-half pound to 13 cubic feet, and 40 beetles were added; in the other naphthalene balls were applied at the rate of one-half pound to 10 cubic feet, and 30 beetles were added. Four weeks after treatment all of the beetles were dead and no larvæ were present in the trunk treated with naphthalene flakes. No live adults, but 3 live and 2 dead larvæ, were found in the trunk treated with naphthalene balls, 8 weeks after treatment, and the flannel was not damaged. In an

untreated trunk there were several live larvæ, and the flannel was slightly damaged at the close of the experiment.

In 5 closed battery-jar tests, in which the adults were tightly confined with a small amount of naphthalene, they were killed in from 2 to 5 days.

Effect on larvæ.—Coarse naphthalene flakes, fine naphthalene flakes, and finely powdered naphthalene, dusted on larvæ infesting flannel, killed 90 to 95 per cent in open-jar tests.

In a closed trunk naphthalene flakes sprinkled on the bottom, at the rate of one-half pound to 13 cubic feet, killed, in 32 days, all of 25 larvæ placed on flannel in a lantern globe, the two ends of which were covered with cheesecloth to prevent the larvæ from coming in direct contact with the naphthalene. The flannel had not been noticeably injured. Naphthalene balls used against larvæ in the same manner, at the rate of one-half pound to 10 cubic feet, gave the same results. The check trunk showed 8 per cent of the larvæ dead and the flannel badly eaten.

These results indicate, as in the case of clothes moths, that the killing effect of naphthalene is due principally to the fumes liberated.

Effect on eggs.—In two open battery-jar tests with naphthalene flakes, applied to small pieces of flannel containing 10 or more eggs each, no eggs were found to have hatched at the end of 11 days. An average of 13 live larvæ was found on the untreated pieces of flannel.

In two similar tests, in which naphthalene balls were used, the results were identical.

Naphthalene was found to be very effective in protecting flannel from infestation by carpet beetles and in killing adults, larvæ, and eggs.

CAMPHOR.

Effect upon carpet-beetle adults.—In a cage test with gum camphor, in which 35 adults were used, no larvæ were found upon the treated flannel at the end of about one month, while 22 live larvæ were found upon the untreated flannel. In a duplicate test, in which 30 adults were used, 1 live and 2 dead larvæ were found at the end of 30 days.

Thirty adult beetles confined in a tight trunk containing one-half pound of camphor to 9 cubic feet were dead at the end of 30 days, and no larvæ were found to be present. In an untreated trunk 10 live larvæ were found at the end of 30 days, and the flannel had been slightly eaten.

Five closed battery-jar tests, in each of which 5 to 10 beetles were tightly confined with flannel treated with a small amount of camphor, resulted in the killing of 80 to 100 per cent in from 4 to 7 days.

Effect on larvæ.—A trunk test against larvæ was made, using camphor at the rate of one-half pound to 9 cubic feet. Twenty-five larvæ on flannel in a lantern globe were added. Observations showed, at the end of one month, that 72 per cent of the larvæ had been killed. In an untreated trunk only 8 per cent were dead in one month.

Camphor sprinkled over larvæ on flannel in open battery jars killed only a small percentage. In tests with the jars sealed, all the larvæ were killed in from 15 to 29 days, but none were killed in seven days. Only 15 per cent died in the untreated jars in 29 days.

Effect on eggs.—In two tests with camphor scattered on flannel containing 10 or more eggs, no larvæ were found to have hatched in 11 days, while an average of 13 live larvæ was found on the untreated pieces of flannel used as a check.

Camphor, although effective against the various stages of the carpet beetle, was not as uniformly efficient as was naphthalene. Since camphor kills more slowly and volatilizes much more rapidly than does naphthalene, its use is not recommended when naphthalene is available.

RED-CEDAR CHEST.

Killing effect on carpet-beetle adults, larvæ, and eggs.—Thirty adults and a large piece of flannel were confined in a red-cedar chest of 10 cubic feet capacity. At the end of 60 days examination showed that all adults were dead and that one live and more than 100 small dead larvæ were present. No noticeable injury had been done to the flannel.

Twenty-five half to full-grown larvæ, placed upon flannel, were confined in the chest for 60 days. At the end of that time none were found dead, and the flannel had been slightly eaten.

Two pieces of flannel, each containing 10 or more eggs, were inclosed in the chest for 23 days. At the end of that time examination showed 14 small dead larvæ on each piece of flannel. The flannel was not damaged. Although the cedar chest failed to kill the eggs, the newly hatched larvæ died almost immediately.

The cedar chest readily killed newly hatched larvæ, but failed to kill adults before eggs were laid and also did not kill one-half to full-grown larvæ. This cedar chest was the same one used in the clothes-moth test.

CEDAR CHIPS.

Effect on carpet-beetle adults.—Cedar chips were employed in three cage tests, about 30 adult beetles being used in each. Examination of the three tests 30 days later showed an average of 10 live larvæ on the treated flannel and an average of 16 live larvæ on the untreated.

Thirty adults, with a large piece of flannel, were inclosed in a trunk, to which had been added cedar chips at the rate of one-half pound to 9 cubic feet. At the end of 8 weeks all the adults were dead and no larvæ were present. The check trunk showed 10 live larvæ and the flannel slightly eaten.

Adults placed in closed battery jars with flannel treated with cedar chips resulted in the killing of 80 to 100 per cent in 7 days.

Effect on larvæ.—Red-cedar chips were placed in a trunk at the rate of one-half pound to 9 cubic feet. Twenty-five half to full-grown larvæ were added and the trunk closed immediately. At the end of 56 days no larvæ were dead, and the flannel was considerably eaten.

Effect on eggs.—Red-cedar chips were used in open battery jars against the eggs. After 9 days larvæ were observed on the flannel, but were not counted.

Apparently red-cedar chips were not very effective against the different stages of the carpet beetle. Clothing would be protected by the use of cedar chips only when used very liberally.

PYRETHRUM POWDER.

Effect on larvæ and eggs.—Pyrethrum powder was used in four tests against larvæ on flannel in open battery jars. An average of 27.5 per cent was killed in about a week.

Two tests were conducted with pyrethrum powder against larvæ on flannel in large-stoppered bottles. Of a total of 20 larvæ used, 90 per cent were killed in about one week. Fifteen per cent of the larvæ on untreated flannel in stoppered bottles died in the same time.

Two pieces of flannel, each containing 10 or more eggs, were placed in battery jars and dusted with the powder. At the end of 26 days no larvæ were found on the treated flannel, although the eggs may have hatched and the young larvæ have been killed almost immediately. An average of 13 live larvæ was found on the untreated pieces of flannel.

Pyrethrum powder proved considerably less effective against carpet-beetle larvæ than against clothes-moth larvæ.

HYDROCARBON OILS AND OIL EMULSIONS.

Effect on carpet-beetle adults, larvæ, and eggs.—A 10 per cent solution of carbolic acid showed moderate protective value against carpet-beetle adults in cage tests, while a 5 per cent solution proved ineffective.

Mineral oils and oil emulsions of the nature of kerosene killed all the larvæ when used undiluted. The oil emulsions proved effective

when diluted not more than 1 part to 10 parts of water. Against eggs, in two tests each, a 3, 5, and 10 per cent solution of crude carbo-lic acid appeared to prevent hatching.

SOAP.

Effect on carpet-beetle larvæ and eggs.—Fish-oil soap, used at the rate of 1 pound to 4 and 8 gallons of water, killed 100 per cent of the larvæ. When used at the rates of 1 pound to 10, 16, and 25 gallons, from 75 to 90 per cent were killed, while weaker solutions proved ineffective. Practically the same results were obtained by the use of laundry soap.

Laundry soap, used at the rate of 1 pound to 10 gallons of water, appeared to kill all carpet-beetle eggs in two tests. When used at the rates of 1 pound to 20 and 40 gallons of water it was not effective against the eggs.

NICOTINE SOLUTIONS AND TOBACCO POWDERS.

Effect on carpet-beetle larvæ.—Table VIII shows the results of tests with nicotine in various forms against the carpet-beetle larvæ.

TABLE VIII.—Tests of the killing effect of nicotine solutions and tobacco powders upon carpet-beetle larvæ.

Ex- peri- ment No.	Nicotine, amount and form.	Dilution in water.	Number of tests.	Treated.		Un- treated.
				Total number of larvæ used.	Average per cent dead.	Average per cent dead.
1	40 per cent nicotine as sulphate.....	1 to 10.....	2	20	100	6
2	do.....	1 to 25.....	2	20	60	6
3	do.....	1 to 50.....	2	20	20	6
4	40 per cent nicotine as extract in nicotine- water solution.	1 to 25.....	2	20	75	.....
5	do.....	1 to 50.....	4	40	47.5	.....
6	do.....	1 to 100.....	2	20	5	.....
7	12.5 per cent nicotine in nicotine-water solu- tion.	1 to 125.....	3	30	70	10
8	11.6 per cent nicotine in nicotine-water solu- tion.	1 to 32.....	8	80	72.5	4
9	4.56 per cent nicotine in tobacco dust.....	Undiluted.....	2	20	5	.....
10	0.41 per cent nicotine in tobacco dust.....	do.....	2	20	5	.....

As will be noted, it was necessary to use a tobacco extract (40 per cent nicotine, as sulphate) diluted at the rate of 1 part to 10 parts of water to kill all the larvæ. All weaker dilutions used failed to kill more than 75 per cent. It is therefore apparent that nicotine sprays are not to be recommended for carpet-beetle larvæ.

Powdered tobacco, containing 4.56 per cent of nicotine, which is considerably above the average percentage of nicotine content for such powders, was ineffective against the larvæ when used as a dust.

In addition to the foregoing tests tobacco powder containing 0.85 per cent nicotine was burned in a box at the rate of 6 ounces to 360 cubic feet. None of the 15 larvæ used in this box fumigation were killed in 19 hours. The strength was increased to 26 ounces to 360 cubic feet with the result that 20 per cent of the larvæ were killed.

Effect on eggs.—A solution containing 40 per cent nicotine extract, used at dilutions of 1 part mixture to 25 and 1 to 50, killed nearly all the eggs, while dilutions of 1 to 75 and 1 to 100 were not effective.

It appears from these tests that the various forms of nicotine are of no practical value against carpet beetles.

MISCELLANEOUS SUBSTANCES.

Effect on carpet-beetle adults.—Oil of cedar leaves effectively protected flannel from carpet-beetle infestation in laboratory-cage tests. Lavender flowers were ineffective in such tests. Formaldehyde fumigation ($2\frac{1}{3}$ ounces to 360 cubic feet) proved ineffective against adults.

Effect on larvæ.—Miscellaneous substances tested against carpet-beetle larvæ and found to be more or less effective are as follows:

Alcohol (ethyl), 50-95 per cent solutions.
Cloves (powdered).
Gasoline (undiluted).
Mercuric chlorid (1 pound to 50 gallons of water).
Sulphur (burned), $8\frac{1}{2}$ ounces to 360 cubic feet.

Miscellaneous substances found to be ineffective against larvæ are as follows:

Alcohol (ethyl) 20 to 40 per cent solutions (sprayed).	Hellebore (dust).
Allspice (dust).	Lavender flowers (dust).
Arsenious acid (dust).	Lime (dust).
Borax (dust).	Pepper, black (dust).
Formaldehyde (fumigation).	Sodium fluorid (dust).
	Sulphur (dust).

Effect on eggs.—Solutions of ethyl alcohol at 30, 50, 70, and 100 per cent appeared to prevent the hatching of carpet-beetle eggs. A 20 per cent solution, however, was of no value.

Borax, gasoline, mercuric chlorid (1 pound to 50 gallons of water), and sulphur failed to prevent hatching of eggs.

HEAT.

Effect on carpet-beetle larvæ.—Tests of the effect of heat were conducted by placing 10 larvæ on flannel in an incubator for varying lengths of time. The results are shown in Table IX.

TABLE IX.—*Effect of heat on carpet-beetle larvæ.*

Length of exposure.	Degree of heat.	Results.
<i>Minutes.</i>	<i>° F.</i>	<i>Per cent killed.</i>
10	128	100
15	125	100
30	120	100
10	120	30
30	110	0
10	110	0
30	105	0

Effect on eggs.—Ten or more eggs on a piece of flannel were placed in an incubator for varying lengths of time. The results are shown in Table X.

TABLE X.—*Effect of heat on carpet-beetle eggs.*

Length of exposure.	Degree of heat.	Result.
<i>Minutes.</i>	<i>° F.</i>	<i>Per cent killed.</i>
11	130	100
11	128	50
19	125	100
16	125	100
31	120	0
11	120	0
31	110	0
11	110	0
31	105	0

To kill all larvæ, a temperature of 120° F. maintained for 30 minutes was required. Higher temperatures for less time were equally efficient. To prevent all eggs from hatching, it would appear, from these limited tests, that the length of exposure is more important than the temperature. A temperature of 125° F. for 16 minutes killed the eggs, while an exposure of 128° F. for 11 minutes failed to kill all the eggs.

Two pieces of flannel, each containing 10 or more eggs, were placed in the hot sun for three hours. The temperature on the flannel ranged from 109° F. to 120° F. Observations showed that none of the eggs so exposed hatched, while practically all the eggs on the unexposed flannel hatched.

HOT WATER.

Effect on carpet-beetle larvæ and eggs.—Flannel dipped for five seconds in water at a temperature of 140° F. resulted in the killing of both larvæ and eggs, while water at a temperature of 122° F. failed to kill either larvæ or eggs.

SUMMARY.

1. Naphthalene, against carpet beetles, as against clothes moths, proved effective in preventing infestation of clothing and in killing all stages of the insect.

2. Camphor was effective against the various stages of the carpet beetle, but killed much more slowly than did naphthalene.

3. A red-cedar chest killed adults and newly hatched larvæ, but had no effect on larvæ half grown or larger.

4. Red-cedar chips proved only moderately effective against carpet beetles.

5. Pyrethrum powder proved considerably less effective against carpet-beetle larvæ than it did against clothes-moth larvæ.

6. Various mixtures of mineral oils killed carpet-beetle larvæ, when used undiluted or but slightly diluted.

7. Laundry soap killed both larvæ and eggs when used in strong solutions.

8. Nicotine solutions and tobacco powders proved of no practical value against this insect.

9. Oil of cedar leaves was effective, and lavender flowers ineffective, in protecting flannel from carpet-beetle infestation.

10. Ethyl alcohol (50-95 per cent solutions), powdered cloves, gasoline, mercuric chlorid, and fumigation with sulphur (8½ ounces to 360 cubic feet) killed the larvæ effectively.

11. Ethyl alcohol (20 to 40 per cent solutions), allspice, arsenious acid, borax, formaldehyde fumigation, hellebore, lavender flowers, lime, black pepper, sodium fluorid, and sulphur were ineffective against the larvæ.

12. Ethyl alcohol (30, 50, 70, and 100 per cent solutions) killed carpet-beetle eggs, while borax, gasoline, mercuric chlorid, and sulphur failed to kill the eggs.

13. Heat killed the larvæ, when exposed in an incubator for 30 minutes at 120° F. A higher temperature was required to kill the eggs.

14. Hot water killed both larvæ and eggs, when the infested flannel was dipped for five seconds at a temperature of 140° F.

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WM. A. TAYLOR, Chief



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PROFESSIONAL PAPER

September 18, 1918

SHUCK PROTECTION FOR EAR CORN.

By C. H. KYLE, *Assistant Physiologist, Office of Corn Investigations.*

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INTRODUCTION.

Most corn growers fail to realize that by improving the shuck covering on their corn by selection they may reduce the amount of damage done to the grain. Growers generally consider nothing but the ears and kernels when selecting seed. In weevil-infested sections in particular, variation in the damage of ears is frequently observed, but if the matter is considered the cause is usually attributed to variation in the hardness of the grain. Weevils attack corn of all degrees of hardness, and their progress in consuming the hard corn is only slower than that in the soft corn. Some observers have concluded that since weevils are able to eat the hardest corn, they would also cut their way through the most resistant shucks in order to feed upon the grain, if sufficiently urged by hunger. Others have observed that earworms may cut holes through a large percentage of the protecting shucks and that weevils will enter through these holes, and they have concluded from this that shuck covering can not be made a practicable means of protection. Then, too, there is a sentiment on the part of some against a large amount of shuck.

With such a formidable array of misconceptions and real difficulties as these and others, it is not surprising that little or no action

is being taken in the matter to bring about practical results. This is especially true in view of the fact that very little experimental work has been done to determine the relationship that really exists between shucks and the corn inclosed by them. However, some reassuring observations in this connection have been recorded by W. E. Hinds, entomologist of the Alabama Agricultural Experiment Station.¹ Below are given certain significant quotations:

The earliest maturing corn—almost regardless of variety—attracts them [weevils] in greatest number and naturally the ears that have exposed tips and loose, open husks are then the first and most heavily attacked. * * * But naturally the corn from the outer edges of the field and the poorly covered ears throughout the field will always contain more weevils than any other equal number of ears. * * * The two most important factors in producing this [weevil infestation] variation [of varieties] are generally comparative rapidity of development to maturity of the grain and the relative length and tightness of the husk covering. * * * From our study of these varieties, we have become convinced that weevil resistance depends first of all upon the length and tightness of the husk covering upon the maturing ear. * * * Long husks can be bred by selection in any variety. * * * Good husk covering and proper storage methods may entirely prevent the necessity for fumigation treatment.

In the following pages are given the results of investigations whose object has been to establish definitely by positive means some of the more important facts regarding the merits of shucks as a means of preventing ear damage.

RELATION OF SHUCK CHARACTERS TO INSECT INFESTATION.

FIELD INVESTIGATIONS.

The field investigations described in this bulletin were conducted during the period from September 27 to October 4, 1915. The experimental corn had been planted on March 22 and 23 at Thomasville, Ga., and was among the first planted in the community that year. At the time the data were collected the moisture in the grain varied with the variety from 12.5 to 15 per cent.

Fourteen native southern varieties were included in the investigations. They were grown in adjacent rows and harvested and studied separately, but for the purposes of this bulletin the results are considered collectively.

The ears were harvested with all of the shucks in place. They were then separated into three classes, termed "poor shucks," "good shucks without wormholes," and "good shucks with wormholes."

Ears were classified as having poor shucks if the shucks failed to extend beyond the tip of the ear or if extending beyond the tip they did not close tightly and seemed to offer opportunity for insects to enter along the passage used by the silks.

¹ Hinds, W. E. Reducing insect injury to seed corn. Ala. Agr. Exp. Sta. Bul. 176, p. 49-68, 4 pl. 1914.

Ears were classified as having good shucks if the shucks extended beyond the tip of the ear and closed more or less tightly about the silks. Most of the so-called good shucks were not ideal or such as would be the breeder's aim, but were only better than those classed as poor shucks.

If a hole or holes had been cut through a good shuck by a worm, the ear was put in the class of good shucks with wormholes; if no such openings had been made, the ear was classified as good shucks without wormholes. Only such wormholes as were cut through the shucks were considered. It was found, after removing the shucks, that some of the ears in the class good shucks without wormholes had been attacked by worms, too. They had entered through the silk channel and had either left through the same channel or died.

While the shucks were being removed an examination was made for the work of the earworm and for insect infestation, mold, and discoloration. The number of ears infested with insects or damaged by molds and discoloration was thus determined for each class of shuck covering.

At the time the notes were taken the earworms (*Heliothis obsoleta* Fab.) had completed their work. The black weevils (fig. 1) and a group composed of two or more species of small reddish brown beetles (fig. 2) were practically all the insects which infested the ears at that time. In this bulletin the black weevils are therefore termed "weevils" and the small reddish brown beetles are termed "beetles."

In making counts an ear was considered infested when only a single insect was found inside the shuck covering.

Practically without exception ears infested with weevils were also infested with beetles. For this reason the number of ears infested with beetles is the same as the total number of ears infested with insects.

The results of the investigations of the relation of the shuck covering to insect infestation are summarized in Table I.

TABLE I.—Relation of the shuck covering of corn to insect infestation in the field.

Kind of shuck covering.	Percentage of ears—		
	In each class of shucks.	Infested with—	
		Weevils.	Beetles.
Poor.....	48	52	96
Good, with wormholes.....	28	38	93
Good, without wormholes.....	25	9	56
Total.....		38	85

The total number of ears examined was 1,949. Of these, 48 per cent were in poor shucks, 28 per cent in good shucks with wormholes, and 25 per cent in good shucks without wormholes.

Of the ears in poor shucks, 52 per cent were infested with weevils and 96 per cent with beetles. Of the ears in good shucks with wormholes, 38 per cent were infested with weevils and 93 per cent with beetles. Of the ears in good shucks without wormholes, 9 per cent were infested with weevils and 56 per cent with beetles.



FIG. 1.—Black weevils (*Calandra oryza*), termed "weevils" in this bulletin.



FIG. 2.—Species of small reddish brown insects, termed "beetles" in this bulletin.

A comparison of the classes with different shuck coverings shows 43 per cent more weevil infestation and 40 per cent more beetle infestation in poor shucks than in good shucks without wormholes. The wormholes through what was otherwise good shuck coverings permitted increased infestation amounting to 29 per cent for weevils and 37 per cent for beetles.

Thirty-eight per cent of all the ears examined were infested with weevils and 85 per cent with beetles. From the standpoint of infestation the beetles were the most serious of the two classes of insects; however, close examination failed to discover any damage

that could be definitely attributed to them. As there was abundant evidence of damage due to the weevils, it was concluded that so far as these two classes of insects were concerned the weevils, though greatly outnumbered by the beetles, had undoubtedly done most of the actual damage to the grain.

STORAGE INVESTIGATIONS.

Representative ears in their shucks were taken from the plat in which the field investigations were made and stored in a tight galvanized-iron bin. In August, 1916, or about 10 months after the corn was first stored, the ears were classified in accordance with the kind of shuck covering found and then carefully examined for insect infestation.

Table II shows the relation of the shuck covering to the percentage of ears infested with weevils and beetles.

TABLE II.—*Relation of the shuck covering of corn to insect infestation after 10 months in storage.*

Kind of shuck covering.	Percentage of ears—		
	Infested with—		Not infested.
	Weevils.	Beetles.	
Poor.....	97	100	.....
Good, with wormholes.....	55	100	.....
Good, without wormholes.....	4	77	23
Total.....	66	95	5

A total of 206 ears was examined. Of the ears in poor shucks, 97 per cent were infested with weevils (Pl. I) and 100 per cent with beetles, none being free from infestation. Of the ears in good shucks with wormholes, 55 per cent were infested with weevils and 100 per cent with beetles, while none was free from infestation. Of the ears in good shucks without wormholes, 4 per cent were infested with weevils and 77 per cent with beetles, 23 per cent being free from all infestation (Pl. II).

A comparison of the classes with different shuck coverings showed 93 per cent more weevil infestation and 23 per cent more beetle infestation in poor shucks than in good shucks without wormholes. The wormholes through what was otherwise good shuck coverings permitted increased infestation amounting to 51 per cent for weevils and 23 per cent for beetles.

In this, as in the field investigations, it was found that beetles infested many more ears than the weevils. If they were a factor in damaging ear corn of adapted varieties, the shuck covering would be

much less important as a means of protection. Fortunately, this did not appear to be the case, as is shown by the data given in Table III.

TABLE III.—*Relative amount of damage done to corn by weevils and by beetles.*

Infestation.	Total number of ears.	Percentage of—	
		Ears with damaged kernels.	Damaged kernels.
Weevils and beetles together.....	135	100	60 to 75
Beetles alone.....	60	5	Trace.

From 60 to 75 per cent of all the kernels on the 135 ears infested with weevils and beetles together were seriously damaged. Of the 60 ears infested with beetles alone, 5 per cent were damaged by something. It is possible that worms or other insects not present at the time of the examination might have been the cause of this damage. At any rate the damage amounted to a mere trace on 11 kernels. It is evident, therefore, that the beetles when alone were of no practical importance in the corn studied. The 11 kernels whose damage is in question were softer than most of those in the varieties used in these studies. If the beetles did this damage, then it is probable that they did so because the comparative softness made it possible. Other investigations have shown that some of the comparatively soft-grain varieties of corn from outside the areas that are badly infested with grain insects may be directly damaged by beetles. This again suggests that kernel density may determine whether direct damage from beetles is possible, and emphasizes the importance of using adapted corn which may involve protective factors that have not yet been clearly recognized. Because of the importance of adapted varieties for practical purposes this publication is confined to the results with such varieties, and since the beetles were not an important damaging factor in this connection, these insects are not further considered here.

The lots of corn considered in Tables I and II were grown in the same plat and harvested at the same time, and were as comparable as it is possible for two lots of ears to be under similar circumstances. As the lot considered in Table I was examined for infestation at harvest time (October, 1915), and the lot considered in Table II was examined for infestation after about 10 months in storage (August, 1916), the differences between the percentages of infestation found at the time of examination should represent the gain in infestation during storage. The percentages of weevil infestation shown in Tables I and II are compared in Table IV.

TABLE IV.—*Relation of the shuck covering of corn to the increase in weevil infestation during storage.*

Kind of shuck covering.	Percentage of ears infested.		Increase or decrease during storage.
	October, 1915.	August, 1916.	
Poor.....	52	97	45
Good, with wormholes.....	38	55	17
Good, without wormholes.....	9	4	— 5

Of the ears in poor shucks, 52 per cent were infested in 1915 and 97 per cent in 1916. The infestation in 1916 was 45 per cent greater than in 1915. Of the ears in good shucks with wormholes, 38 per cent were infested in 1915 and 55 per cent in 1916. The infestation in 1916 was 17 per cent greater than in 1915. Of the ears in good shucks without wormholes, 9 per cent were infested in 1915 and 4 per cent in 1916. The infestation in 1916 was 5 per cent less than in 1915.

It seems a significant fact that during the period of storage the percentage of weevil-infested ears increased decidedly in poor shucks and in good shucks with wormholes, but there was no increase in the percentage of ears infested in good shucks without wormholes. These data, coupled with the fact that no evidence could be found showing that weevils attempt to cut the shucks, indicate that the right kind of shuck covering is an effective barrier to this class of insects.

LABORATORY INVESTIGATIONS.

It is probable that the insects in seeking their food follow the line of least resistance. Under ordinary field and storage conditions they naturally attack the ears with least protection first and successively attack those with greater protection as the demand for food increases. While the investigations discussed on the preceding pages show that the better class of shuck protection successfully resisted insect damage under existing conditions, it is natural to suppose that insects which can eat the hardest kernels (fig. 3) of corn would also cut their way through the protecting shucks if sufficiently urged by hunger. With ordinary field and storage conditions it has always been possible for weevils to find some food, and for this reason it was not necessary to force a way to the corn in the best shucks in order that they might avoid extinction. With complete success in the breeding of ideal shuck coverings this last condition might arise, and it is desirable to know whether the acquired shuck coverings would prevent infestation under such conditions. To determine this point a number of weevils were confined in properly ventilated jars with ears of corn in good shuck coverings, but with no other source of food. The test was

begun in August, while the temperature was high and the weevils very active. By the following December all the weevils were dead and dry, none had reached the grain, and no evidence could be

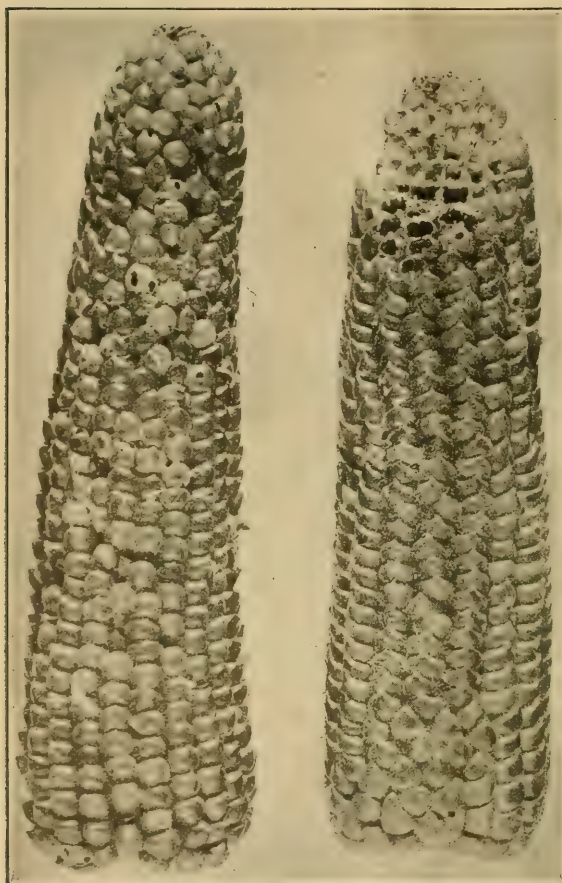


FIG. 3.—White Rice pop corn damaged by weevils. These insects can eat the hardest corn.

found that they had attempted to force their way through the shuck protection to the grain.

As a logical part of this test, some weevils were confined in jars with ears of corn from which the shucks had been removed. This part of the test was identical with the first, with the exception that in this case there was no shuck protection. With four or five exceptions, the weevils were alive at the final examination and had done a very serious amount of damage to all the ears.

This test makes it evident that while it seems that these insects should be quite able to cut through

all of the shuck covering that corn may have, they, in fact, will not do so, even though they must starve if they do not.

RESULTS OF INVESTIGATIONS IN 1916.

On October 6, 1916, at Thomasville, Ga., a quantity of corn was selected from a field and examined for ear damage. The variety in this case was one of those used in the 1915 investigations. As may be gathered from the data, it had a wide range of protective adaptation. As the field was located about one-fourth of a mile from places where old infested corn was stored, the opportunity for weevil infestation was very good. The worm damage is believed to have been exceptionally severe.

The ears examined were of three classes. The first class had shucks extending from 4 to 6 inches and the second class from 2 to 3 inches beyond the tips of the ears; the third class had practically no shucks extending beyond the tips of the ears. The relation of shuck covering to infestation as it was found in these classes is shown in Table V.

TABLE V.—*Relation of the shuck covering of corn to insect infestation in 1916.*

Kind of shuck covering.	Number of ears examined.	Percentage of ears—		
		Attacked by worms.	Infested with weevils.	Affected with worm mold.
Extending 4 to 6 inches beyond tips of ears.....	111	72	9	64
Extending 2 to 3 inches beyond tips of ears.....	102	87	22	77
Practically no extension.....	100	96	100	91

Of the 111 ears with shucks extending from 4 to 6 inches beyond the tips of the ears, 72 per cent had been attacked by worms, 9 per cent had been infested by weevils, and 64 per cent had been affected with worm mold. Of the 102 ears with shucks extending from 2 to 3 inches beyond the tips of the ears, 87 per cent had been attacked by worms, 22 per cent had been infested with weevils, and 77 per cent had been affected with worm mold. Of the 100 ears with practically no shuck extension beyond the tips of the ears, 96 per cent had been attacked by worms, 100 per cent had been infested by weevils, and 91 per cent had been affected with worm mold.

In the case of worms, 15 per cent fewer ears were attacked in the 4 to 6 inch extension shucks than in those having 2 to 3 inch extensions, and 24 per cent fewer than where there was practically no extension. There were 13 per cent fewer ears infested with weevils in the 4 to 6 inch than in the 2 to 3 inch extension shucks and 91 per cent fewer than in the shucks having practically no extension, while 13 per cent fewer ears were affected with worm mold in the 4 to 6 inch extension shucks than in the 2 to 3 inch extension shucks, and 27 per cent fewer than in those having practically no extension.

These figures make it clear that length of shuck extension is a controlling factor in the matter of ear damage. In addition, the relationship between the length of shuck extension and the percentage of ears attacked by worms is of special interest because, in connection with the following evidence, it suggests a possible means of overcoming the most serious obstacle in the way of making a perfectly effective shuck protection for practically all of the ears.

SHUCK EXTENSION AS A PREVENTIVE OF WORM DAMAGE.

The foregoing discussion has made it clear that earworms may be responsible (directly and indirectly) for much damage to corn. The fact that earworms can and sometimes do cut holes through a

large percentage of the protecting shucks would seem to be an insurmountable barrier to those who would breed for shuck protection against weevils. It has been shown (Table V), however, that the proportion of ears attacked by worms tends to decrease as the shuck extension is increased.

The earworms usually enter the shuck coverings through the silk channels, feeding on the silk as they go, the holes through the shucks being made when they are leaving. If while feeding on the silks and with its hunger not yet satisfied a worm reaches an ear which is sufficiently tender to be attractive, it may feed upon the kernels and cob for a time before cutting out. If, however, during its progress along the silk channel the silks become unpalatable on account of age or the worm reaches maturity, it may abandon its course before reaching the ear. Reasoning along this line, one naturally concludes that the longer the shuck extension or silk channel the more likely it is that worms will leave the shucks before they reach the grain. This conclusion is supported by the data presented in Table VI. The ears examined for this information were a part of those examined to obtain the information given in Table V.

TABLE VI.—*Relation of the length of shuck extension of ears of corn to the worm damage.*

Kind of shuck covering.	Total number of ears examined.	Percentage of ears not eaten because worms cut from silk channels before reaching the grain.
Extending 4 to 6 inches beyond tips of ears.....	111	14
Extending 2 to 3 inches beyond tips of ears.....	102	7
Advantage due to the longer shuck extension.....		7

It may be seen that of the 111 ears with shucks extending from 4 to 6 inches beyond the tips of the ears, 14 per cent had escaped damage because the worms had cut from the silk channels before reaching them. It may also be seen that of the 102 ears with shucks extending from 2 to 3 inches beyond the tips of the ears, 7 per cent had escaped damage because the worms had cut from the silk channels before reaching them.

By comparison it may be seen that the longer shuck extension afforded 7 per cent more protection than the shorter shuck extension.

These investigations, in part at least, show why shuck extension reduces the amount of worm damage. In addition, they suggest the possibility of breeding a shuck extension long enough to be entirely effective against earworms. The extent to which the earworms can be eliminated by the means suggested can only be determined by other investigations.

RELATION OF SHUCK COVERING TO MOLD AND DISCOLORATION.

The relation of shuck covering to the mold and discoloration of corn was studied in the field in connection with the investigations in 1915 of the relation of shuck covering to insect infestation. The affected ears were classed as rotten, discolored, or worm moldy.

Those ears termed "rotten" were extensively affected by molds and would have been rejected by anyone culling to improve the grade of the corn.

Those ears termed "discolored" had some kernels slightly affected by molds, stained by the shucks, checked by small cracks, or they were tarnished as though they had been soaked in water. Most of this discoloration would not have been given serious consideration by the average observer.

The ears termed "worm moldy" were such as were affected by mold that seemed to have been made possible by the attacks of earworms. These ears, because of their large number and the slight damage done, would not have been discarded by the most fastidious in an attempt to improve the grade.

As this corn was examined comparatively early in the fall, a large percentage of the stalks standing erect and the ears not shaded by vines, weeds, or other growth, and as the seasonal conditions for drying the mature ears were favorable, the proportion of damaged corn was much less than may often be seen in the section covered by these investigations.

For these investigations the ears were separated into classes with poor shucks and with good shucks. The class with good shucks includes both those with and without wormholes. In other respects the classification is the same as that for the investigations involving insects. The results of the investigations of the relation of the shuck covering to rotten, discolored, and worm-moldy ears are summarized in Table VII.

TABLE VII.—*Relation of shuck covering to the percentage of ears of corn found to be rotten, discolored, or having worm molds.*

Kind of shuck covering.	Percentage of ears—		
	Rotten.	Discolored.	Worm moldy.
Poor.....	4	34	58
Good.....	1	18	40
Total.....	3	27	50

A total of 1,157 ears was examined. Of the ears in poor shucks, 4 per cent were rotten, 34 per cent were discolored, and 58 per cent were affected with worm mold. Of the ears in good shucks, 1 per cent

were rotten, while 18 per cent were discolored and 40 per cent were worm moldy.

A comparison of the classes with different shuck coverings shows that 3 per cent more ears in poor shucks than in good shucks were rotten, 16 per cent more were discolored, and 18 per cent more were affected with worm mold.

GENERAL VALUE OF A GOOD SHUCK COVERING.

Of all the ears of corn produced in the United States each year, comparatively few entirely escape damage. Most of them lose only a few kernels because of earworms or other insects or are more or less reduced in value by molds or discoloration. This damage is usually passed without concern, but when it is considered that a loss of only one kernel per ear amounts to an annual loss for the United States of at least 5,000,000 bushels and that this amount must be multiplied several times to represent the total annual loss, it becomes apparent that these losses are worthy of attention. It seems that by improving the shuck protection ear damage in any section can be considerably reduced, but such protection can be made of the greatest value in sections infested with weevils. Some special advantages of shuck protection in a weevil-infested section are mentioned below.

ADVANTAGES IN THE FIELD.

The relation of the shuck covering to the percentage of damaged kernels is illustrated by the figures presented in Table VIII. These data were obtained on October 6, 1916, from two of the lots of ears considered in Table V.

TABLE VIII.—*Relation of the shuck covering of corn to the percentage of damaged kernels.*

Kind of shuck covering.	Number of ears examined.	Percentage of kernels damaged.			Total.
		By weevils.	By ear-worms.	By worm mold.	
With practically no extension.....	100	14	6	a 4	20
With an extension of 4 to 6 inches beyond the tips of the ears.....	111	0	1	a 1	1
Advantage in favor of shuck extension.....		14	5		19

a These figures are included in those for worm-eaten kernels.

With practically no shuck extension, 14 per cent of the kernels were damaged by weevils, 6 per cent by worms, and 4 per cent by worm mold. No kernels with shuck extensions of 4 to 6 inches were damaged by weevils, 1 per cent were damaged by worms, and 1 per cent by worm mold. The ears in shucks with practically no extension had a total of 20 per cent of their kernels damaged, while in the ears with shuck extensions only 1 per cent were damaged. It is evident,

therefore, that the long shuck extension effected a saving of 19 per cent in the field. This saving could not have been effected by earlier harvesting and fumigation, because the corn was taken from the field as soon as it was sufficiently dry to permit storage.

ADVANTAGES IN STORAGE.

There is some conflict of opinion regarding the matter of storing corn in the shuck. Some believe that corn stored in the shuck is more or less protected from weevils because of the shucks. Others reason that these insects enter the shucks in the field and then, being carried with the ears put in storage, they are able to continue their work of destruction. They further reason that if the shucks were removed in the field many of the insects would be left behind, and to that extent the damage would be lessened. The facts presented on the foregoing pages have shown that the right kind of shuck covering is not entered by weevils, but that poor or defective shucks may be entered. It is evident, therefore, that so far as weevil damage is concerned, the advantage or disadvantage of the method of storing corn in the shuck is determined by the kind of shuck covering on the corn stored. A certain number of ears in all varieties are exposed in the field. To store such ears in their shucks after the grain has become infested is to make conditions most favorable for the insects. To shuck them in the field is to leave a part of the insects behind, but as these ears still contain adults, larvæ, and eggs, destruction will continue, and they will remain a source from which uninfested and exposed corn may become infested.

On the other hand, there are usually some ears in varieties native to weevil-infested sections that because of their effective shuck coverings do not become infested with weevils. To store such ears in their unopened shucks is to afford them continued protection. To shuck such ears is to expose them to the attacks of insects, including the Angoumois grain moth, unless they are protected by other means. The average farmer does not use other effective means of protection, because they involve additional cost and, in the case of fumigation with carbon bisulphid, extra fire risk. Shuck protection involves no additional cost and no extra fire risk. It seems, therefore, that a storage method that utilizes shuck protection will very greatly increase the practice of holding and feeding corn on farms in weevil-infested areas. Such a method is outlined as follows: Grow the best shuck-protected corn, store the shuck-protected ears in their shucks, and feed or sell the unprotected ears as early as possible.

If there is a considerable percentage of unprotected ears, as is always the case at present, and these ears are known to be infested, they should be shucked as early as possible and kept away from uninfested corn. The shucking should be done in such a way that the dislodged insects may be swept together and burned.

ADVANTAGES IN MARKET QUALITY.

The price of corn is governed in part by its commercial grade. In order to improve the grade of corn offered on the market, growers are sometimes advised to cull the damaged ears. It is practicable to cull only such as are extensively damaged. After culling, there may be as much or more damaged corn remaining as was removed, because it is scattered through a large percentage of the ears in the form of discolored and worm-moldy kernels. It has been shown (Table VII) that shuck protection reduces both of these kinds of damage. For this reason it also makes possible a higher grade of corn than can otherwise be secured.

RELATION OF INCREASED SHUCK PROTECTION TO THE COST OF SHUCKING.

There is a noticeable variation in the amount and kind of shucks on corn grown in different sections of the United States. Whenever unshucked corn is subjected to weevil attack, the ears with poor shuck protection are more or less damaged and to that extent are eliminated from the corn to be used for seed. This, then, leaves a higher proportion of the sound corn on ears with good shuck protection. For this reason, the natural tendency, with other circumstances favorable, has been toward the use of seed from ears with good shuck protection. So, as a general rule, varieties native to weevil-infested sections have a heavier and longer shuck than those native to sections without weevils. Notwithstanding the overpowering influence of natural circumstances in weevil-infested sections and its weaker influence in other sections, there has been a general tendency on the part of corn growers toward a lighter and shorter shuck. The chief reason for this preference has been the desire to reduce the amount of hand labor required to shuck the ears.

In some varieties commonly grown in weevil-infested sections, the shuck protection can be greatly improved without producing a greater amount of shuck. This can be done by improving the shape of the present shucks by means of selection, having in view longer and closer fitting coverings. Then, too, improved machinery is now available which may be made to meet any objection to the increased quantity of shuck that is necessary to protect the ears. These machines are known as "shuck shellers" and are now commonly used by the larger grain and feed dealers in the South. Either the shucked or unshucked ears, after having been broken from the stalks, are handled by these machines. In the case of ears in the shucks, the shelled grain, the cobs, and the shucks are separated. The shucks are usually baled and sold for feed, but occasionally mattress and other factories take a part of the output. Some of the companies have received inquiries from paper manufacturers regarding the quantity

of shucks they could supply, but up to the present time there has been an insufficient quantity available to justify the paper companies in entering the market for them. Wherever such data could be obtained it was found that the amount obtained from the sale of shucks fully covered the cost of shelling and separation, and there seems to be no chance of an overproduction. It appears, therefore, that increased shuck protection need not increase the present cost of shucking.

THE PRODUCTION OF BETTER SHUCK PROTECTION.

There is abundant evidence to indicate that shuck covering responds to selection. Some of this evidence is summarized as follows: (1) Varieties native to weevil-infested sections usually have a higher percentage of ears in good shucks than do those native to sections where no weevils are found. (2) Varieties native to sections with comparatively few weevils and with poor shuck covering, after having been grown for a number of years in sections very seriously infested with weevils, were found to have as good shuck coverings and as much resistance to weevils as the average native variety. (3) The percentage of ears in good shucks has been increased by systematic selection.

All the known efforts in this line of selection have been of short duration, but they indicate that with similar methods and equal effort progress will be as rapid as that in other lines of selection.

Further investigations are required to determine all the points to be desired in the ideal shuck covering, but it is certain that the portion of the shucks that extends beyond the tips of the ears should be very long and that it should fit tightly about the silks.

The shuck covering can probably be improved in any variety, but some varieties have a greater range of shuck variation than others, and, with other qualities equally good, it would be desirable to start systematic breeding with one of these. Even in those varieties offering the greatest opportunities the ears with ideal shuck extensions are exceptionally rare. With varieties in this low state of selection it will necessarily require several years of the most exacting selection to attain uniform success. The breeder, however, should be encouraged in his efforts by the thought that while he must begin with exceptionally little, the advantage resulting from complete success will be exceptionally pronounced. Certainly the man who has labored to produce higher yields by selection should be attracted by this promising opportunity to save a part of the corn crop. It is usually impossible to prove that the breeder has increased the yielding power of his variety by selection, but the results of selection for better shuck protection are apparent to the eye.

SUMMARY.

The investigations reported upon in this bulletin had for their object the establishment by positive means of some of the most important facts regarding the merits of shucks as a means of preventing damage to ear corn.

Field investigations showed 4; per cent more weevil infestation in corn with poor shucks than in that having good shucks without wormholes.

Storage investigations showed 9; per cent more weevil infestation in corn with poor shucks than in that with good shucks without wormholes.

Laboratory investigations showed that weevils would starve rather than force their way through good shuck covering.

These investigations showed per cent more rotten, 16 per cent more discolored, and 18 per cent more worm-moldy ears in poor shucks than in good shucks.

The so-called good shucks of these investigations were not ideal, but only better than the so-called poor shucks. The later investigations made it clear that the longer the shuck extension beyond the tips of the ears, the more effective is the protection against causes of damage, including earworms. This suggests the possibility of breeding a shuck extension long enough to be entirely effective against ear damage.

Increased shuck protection need not increase the cost of shucking if proper use is made of shuck-shelling machinery.

These investigations appear to justify the following recommendations:

- (1) Breed corn with a very long shuck extension that fits tightly about the silks.
- (2) To better protect ear corn in the fields from weevils, earworms, molds, and discoloration, grow the best shuck-protected corn.
- (3) To make practicable the more general holding and feeding of corn on farms in the weevil-infested areas, store shuck-protected ears in their shucks and feed or sell the unprotected ears as early as possible.

UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 709

Contribution from Bureau of Markets,
CHARLES J. BRAND, Chief.



Washington, D. C.



November 20, 1918

REPORTS OF STORAGE HOLDINGS OF CERTAIN FOOD PRODUCTS.

By JOHN O. BELL, *Assistant in Market Surveys*, and I. C. FRANKLIN, *Specialist in Storage*.

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INTRODUCTION.

The storing of food supplies during the season of production or in times of plenty for use in the season of nonproduction or in times of scarcity is as old as civilization itself. In fact, this custom, not unknown among savage races, is in a sense but the counterpart of the instinctive action of certain provident species of insects and other lower animals in the storing of their particular foods. Among human beings little if any progress could have been made along the road of civilization without intelligent action in the storing of certain nonperishable products, at least, and this custom is one of the first essentials in the development of wealth and power in any race or nation.

The storing of grains and other nonperishable products requires protection merely from moisture and from the greater extremes of temperature. The storing of fresh fruits and vegetables requires the arresting of life processes, and the storing of all perishable products, vegetable or animal, requires control of the development of bacteria. Until quite modern times the preservation of such products was prin-

cipally by the use of salt and other preservatives and by protection from the air, and it was only for limited periods and in moderate quantities that they were preserved in the fresh state by holding them at reduced temperatures. The more palatable and more nutritious character of these products when preserved in the fresh state has given such encouragement to further use of this method of preservation that a complete transformation has resulted in the character and economic importance of the storage industry. Since the year 1890 mechanical refrigeration has assumed great importance in the preservation and marketing of perishable and semiperishable products, and the present importance of the storage industry is in large measure due to the adoption and development of this process.

Aside from the carrying over of perishable and semiperishable foods in household economy from the season of production to the season of nonproduction, there is in the business world a sufficient motive for such preservation in the profit to be gained by buying at lower prices in times of plenty for sale at higher prices in times of scarcity. The commercial motive has been an incentive in the business of storing and preservation of foods at all times, and it exerts an equal force in the work of the cold-storage industry. The consequences, however, are not entirely commercial. Just as in the household the family in the season of nonproduction has the use and enjoyment of the food saved from the season of production, so in the commercial world the preservation of foods for seasons and years of scarcity is provided for by the accumulation of a surplus in times of plenty. The development of the cold-storage industry has made possible the holding of perishable foods in substantially the same condition as that in which they were first produced; and the quantities that will be held in the future under mechanical refrigeration need be limited only by the powers of production of foods and of providing such means of storage and by the prospective demand. Accordingly there have already resulted, and in the future there may be expected to result in even greater degree, economic consequences of the utmost importance.

The preservation of these articles in the fresh state from the season of greatest production to the seasons of scarcity tends to greater uniformity of prices throughout the year. On the one hand it tends to relieve a glutted market, and on the other hand it not only provides a supply in the season of nonproduction of commodities which could not be had at such times in the fresh state at all, but also provides a larger supply, consequently at lower prices, of such products as butter and eggs, which otherwise could be had only in smaller quantities. Of still greater consequence than the equalization of prices is the conservation and avoidance of waste in the season of large supply and the larger consumption because of less excessive prices in the

season of scarcity. Perhaps the greatest advantage of all lies in the widening of the market, the production of foods both in seasons best suited and in regions best adapted to their development, and the placing of them on the market in seasons of scarcity and in communities far remote from the localities of production.

As a result, the interests of producer, middleman, and consumer are brought more closely into harmony. With the assurance that waste will be avoided and that the entire product can be marketed, the producer will be encouraged to increase his output and can afford to sell his product at a lower price per unit. The consumer will inevitably buy on more favorable terms, since the providing of a large supply in seasons of scarcity must lower the extreme prices demanded at such times, and the increase of the total annual supply must result in placing the product on the market upon more favorable terms. The avoidance of waste for the middleman, owing to the holding of perishable products under favorable conditions of temperature during the marketing process, and the moving of such commodities in larger quantities through the markets, must result under conditions of reasonable competition in a smaller margin of profit per unit of the article handled, with corresponding advantage to producer and consumer. While in many instances there may be abuses in the commercial operations of the cold-storage industry, its general economic effects are highly advantageous and under present conditions of life almost indispensable, and its general operations should ordinarily prove commercially advantageous to all parties concerned.

One serious obstacle at present to further growth of this industry is an undue prejudice against commodities that have been held in cold storage. While it is true that in many instances goods held for the usual season in storage are somewhat less palatable than fresh stock, the difference in the price is ordinarily greater than is warranted by the difference in the quality of the goods. When the public has learned to purchase fresh and cold-storage products according to quality, a further increase in the use of cold-storage facilities, and accordingly in economic gain, will undoubtedly follow.

The dealer's success, however, is dependent upon so many factors that the most comprehensive information concerning market conditions is essential to such stability of the industry as will result from conducting cold-storage operations at reasonable and steady profits rather than at alternating excessive profits and losses. The industry can not attain complete success except by reducing the speculative element of the transactions to a minimum.

To this end it is necessary that in the storing season producers and dealers be supplied with information showing how much of each article is being stored, whether the quantity is more or less than usual, and whether under all the circumstances it is going into stor-

age at fair prices. When the stock is moving out of storage it is important to know how fast it is being disposed of, in order that on the one hand the dealer from previous experience or from records may be able to judge how quickly it must be moved to prevent competition with the product of the next season, and on the other hand the consumer may be able to determine whether under all the circumstances the existing supply is being offered at fair prices.

It is apparent that this information has a cumulative value. It is useful when comparisons are made between the current holdings and movements and those of the previous year, but it is more valuable when comparisons are made for a series of years, and its value increases with the completeness of the returns as inclusive of all holdings.

COLD-STORAGE REPORTS OF COMMERCIAL ORGANIZATIONS.

Many trade papers make monthly estimates of the quantities of certain products held in cold storage in various cities on the first of each month. Their sources of information are confidential, but it is well known that they are not based on actual knowledge, as they do not have the cooperation of all operators of warehouses. The data they publish are valuable but are confined to the holdings of a few of the great distributing centers.

For more than 10 years the American Warehousemen's Association has obtained such data from about 54 of the more important storages, regarding their holdings of creamery butter and eggs. The figures they have collected are especially valuable in that they cover a series of years and are based on the business of the same firms for almost the entire period.

The accompanying diagram (fig. 1) shows the average percentage of the creamery-butter holdings in storage on the first of each month of the year as reported to this organization. It is based on the average monthly holdings for a period of 10 years, from 1907 to 1916, inclusive, the average holdings on the 1st of September for the 10 years being 64,378,898 pounds.

It will be observed that more than three-quarters of the holdings in these warehouses are stored during the months of June and July, while most of the distribution is within the months of October to March, inclusive, about one-fourth of the total holdings being withdrawn during December. It appears from these figures that on an average only 6.9 per cent is carried over into the next season.

Figure 2 is a diagram showing the average monthly holdings of case eggs for the same date. The maximum holdings are shown to be in storage on August 1. During April, May, and June 84.5 per cent of all the eggs stored were placed in these warehouses. The deliveries extended over the months of August to February, inclusive, one-fourth of the stock being sold out in December. On the aver-

age, only four-tenths of 1 per cent of the holdings are carried through the month of February. It is the general custom to remove

COLD STORAGE HOLDINGS OF CREAMERY BUTTER

Compiled from the reports of the associated warehouses.
Based on the average holdings of the years
1907 to 1916 inclusive.

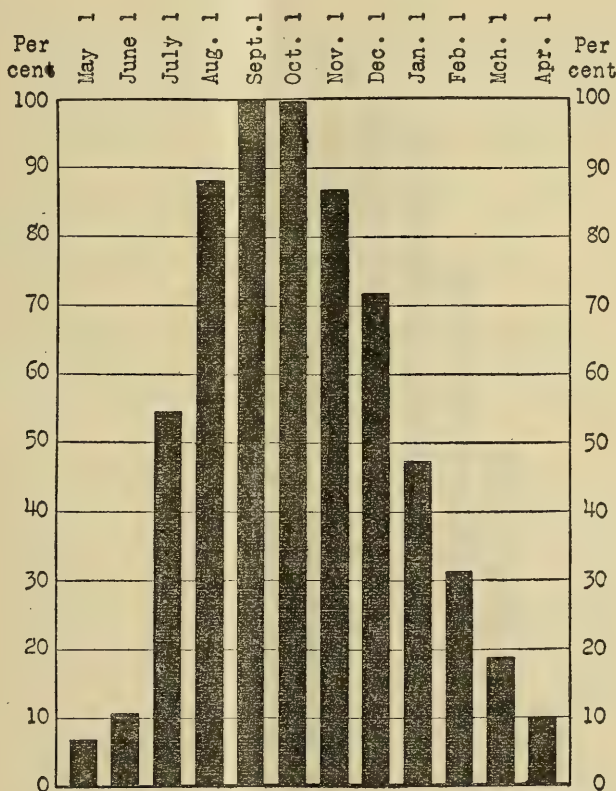


FIG. 1.

first from storage the eggs stored in July. It will be observed that 4.4 per cent of the total is stored during July and 4 per cent removed

during August, thus almost cleaning up the July eggs. The April eggs are the choicest storage stock and comprise 38.4 per cent of

COLD STORAGE HOLDINGS OF CASE EGGS

Compiled from the reports of the associated warehouses.
Based on the average holdings of the years
1907 to 1916 inclusive.

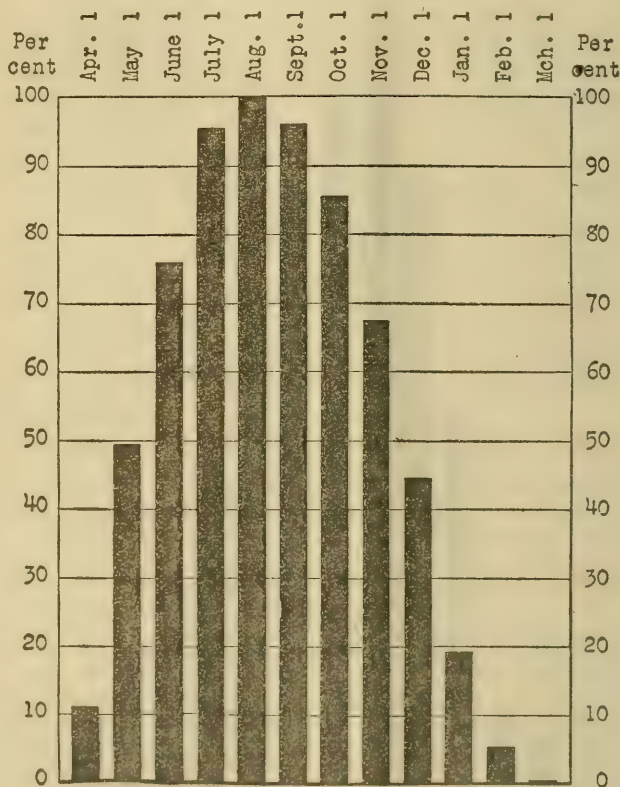


FIG. 2.

the total quantity stored. The average amount in storage on the first of August during the 10 years was 2,913,591 cases.

STORAGE REPORTS OF THE BUREAU OF MARKETS.

The reports of the Bureau of Markets of the United States Department of Agriculture showing the storage holdings of food-stuffs have so far been limited almost entirely to showing the holdings of certain commodities in cold storage. The only exceptions are data showing the quantities of cured beef, dry salt pork, sweet pickled pork either cured or in the process of curing, and lard. It was realized in the beginning that in order to make the information of the most value it should include all of the cold-storage holdings of each article throughout the United States. This would give the dealer actual knowledge of the quantity that was stored and a more complete history of its movement.

BEGINNING AND GROWTH OF THE WORK.

The work was begun in October, 1914, by making preparations for reports covering the holdings of apples in cold storage. The reports for the first two seasons covered the period from December 1 to June 1, inclusive, thus showing the movement from storage only. Since that time they have begun with a report on October 15. Semi-monthly reports are issued until December 1, as the apples are being placed in cold storage at that time and the movement is much more rapid than later.

On August 1, 1916, the Bureau of Markets began reporting the cold-storage holdings of creamery butter and case eggs. American cheese was added to the list of commodities on September 1 of that year, and on December 1, 1916, the work was extended to include reports on seven varieties of meat products: Frozen beef, frozen pork, frozen lamb and mutton, dry salt pork, sweet pickled pork, cured beef, and lard.

On May 1, 1917, the first reports showing the stocks of frozen eggs and frozen poultry were issued. The poultry was divided into four classes: Broilers, roasters, fowls, and turkeys. All other poultry, including the poultry that the warehousemen were unable to classify, was reported under the head of miscellaneous frozen poultry. Packing-stock butter was added to the list on September 1, 1917. On October 15, 1917, the first report showing holdings of frozen fish, cured herring, and mild-cured salmon was issued. The report covers 22 varieties of frozen fish, and other varieties are grouped under the heading of miscellaneous frozen fish. The following are the different classifications:

Bluefish.
Butterfish.
Ciscoes.
Cod, hake, pollack, haddock.
Croakers.

Halibut.
Herring (including alewives, blue-backs, etc.)
Herring, cured.
Lake trout.

Mackerel (excepting Spanish).	Shad.
Rock fishes (including grey and red cod).	Shad roe.
Sablefish (black cod).	Smelts, eulachon, etc.
Salmon, fall.	Squid.
Salmon, silver.	Weakfish.
Salmon, others.	Whitefish.
Sea bass.	Whiting.

In order to relieve the congestion of work on compilations at the first of the month, incidental to the preparation of other storage reports, and thus enable the bureau to handle its work more economically, the reports for fish are obtained for the 15th of each month.

METHODS OF SECURING INFORMATION.

In securing the information two methods were available, one being to obtain reports from the owners of the goods, and the other to obtain the data from the cold-storage warehouses. Obviously one or the other of the methods had to be rigidly adhered to in order to prevent duplications.

The latter method was adopted, as it required a much smaller list of reports with less chance of error, and it was believed that co-operation could be secured more readily from the warehousemen than from the owners of the products. The principal difficulty encountered in the beginning of the work was the lack of any complete list of cold-storage warehouses. Various lists were consulted, but none proved complete. The first apple report was based on the holdings as reported by 289 cold storages. That the list was very incomplete is shown by the fact that the report of June 1, 1917, showed the apple holdings of 569 warehouses.

In June, 1916, the work of compiling a complete list of cold-storage warehouses was begun. Circulars were sent out to a list of more than 3,000 firms compiled from various sources. They were sent to all firms listed in any available records which, judging from their advertisements and descriptions of their business or equipment in trade publications and journals, might be conducting cold-storage plants. In addition, one cooperating firm in each city was asked to furnish a list of all cold-storage plants in that town. The returns were classified and resulted in increasing the list of known cold-storage warehouses to more than 1,000. Since that time many names and addresses have been secured from various sources, and the list has been extended to include packing-house plants having refrigerating apparatus. There were 1,450 names on the list of the Bureau of Markets on January 1, and it is believed it included practically all of the cold-storage plants in the country.

Blank forms are furnished to the cold-storage firms on which to submit their reports. These forms are mailed on the 8th and the 24th

of each month, the form mailed on the 8th being for the reports of the 15th, and those on the 24th to be used for the 1st of the following month. Warehouses in the States of Montana, Wyoming, Colorado, New Mexico, and west thereof are requested to telegraph their reports in addition to submitting the regular form by mail.

Prior to September 1, 1917, the success of the work was dependent upon the voluntary cooperation of the cold-storage warehouses. Naturally in such a large list of firms there were a few delinquents, some of which reported irregularly, and there were a few who absolutely refused their cooperation. Although the reports were not then entirely complete, the statements compiled from them gave a very clear idea as to the quantities stored and the percentage of movement.

After the entrance of the United States into the war the Sixty-fifth Congress passed legislation by which these reports may be required by the Secretary of Agriculture. Section 2 of Public No. 40, approved August 10, 1917, provides as follows:

That the Secretary of Agriculture, with the approval of the President, is authorized to investigate and ascertain the demand for, the supply, consumption, costs, and prices of, and the basic facts, relating to the ownership, production, transportation, manufacture, storage, and distribution of, foods, food materials, feeds, seeds, fertilizers, agricultural implements and machinery, and any article required in connection with the production, distribution, or utilization of food. It shall be the duty of any person, when requested by the Secretary of Agriculture, or any agent acting under his instructions, to answer correctly, to the best of his knowledge, under oath or otherwise, all questions touching his knowledge of any matter authorized to be investigated under this section, or to produce all books, letters, papers, or documents in his possession, or under his control, relating to such matter. Any person who shall, within a reasonable time, to be prescribed by the Secretary of Agriculture, not exceeding 30 days from the date of the request, willfully fail or refuse to answer such questions or to produce such books, letters, papers, or documents, or who shall willfully give any answer that is false or misleading, shall be guilty of a misdemeanor, and upon conviction thereof, shall be punished by a fine not exceeding \$1,000 or by imprisonment not exceeding one year, or both.

On August 17, 1917, the Secretary of Agriculture authorized and instructed the Chief of the Bureau of Markets to take such steps as might be necessary to acquire authoritative information for the purposes of the act. As cold storage is an important factor in the conservation of food, information such as that covered by the monthly storage reports was considered essential to a thorough investigation under the act. Under the provisions of the Act three business days after the 1st or the 15th of each month are allowed by the Secretary for the preparation of the returns, and they must be mailed or telegraphed not later than the fourth business day.

COLD-STORAGE DEFINITIONS.

For the purpose of licensing and regulating cold-storage plants the following definitions were promulgated by the President. They are used by the Food Administration and by the Department of Agriculture:

1. *Cold-storage warehouse*.—A cold-storage warehouse shall mean any place artificially or mechanically cooled to or below a temperature of 45 degrees above zero Fahrenheit in which food products are placed and held for thirty days or more.

2. *Public cold-storage warehousemen*.—Any individual, firm, corporation, or association engaged in the business of maintaining and operating cold-storage warehouses in which food products are stored for hire or compensation, shall be called a public cold-storage warehouseman.

3. *Private cold-storage warehousemen*.—Any individual, firm, corporation, or association that maintains and operates as any adjunct to their business, cold-storage warehouses for the storage of food products exclusively owned or dealt in by them, shall be called a private cold-storage warehouseman.

4. *Combined public and private cold-storage warehousemen*.—Any individual, firm, corporation, or association which combines a public cold-storage warehouse business with a storage of commodities which directly or indirectly it owns, deals in, or otherwise has an interest in shall be called a combined public and private cold-storage warehouseman.

COMPILING THE REPORTS.

In addition to showing the actual quantities of the different commodities as reported from the warehouses, certain comparisons are made with the reports of other months, in order to show the relative amount in storage compared with previous dates and the relative increase or decrease in holdings during the month. In preparing the first reports showing the cold-storage holdings of apples for the season 1914-15, the comparison was made with the holdings of the season 1912-13, as it was believed that the holdings of that season were more nearly normal than those of the season 1913-14. Except for the first season, the holdings of the current year were compared with the holdings on the same date of the previous year. For the first season only, the total holdings of the United States were used in the comparison; but at the beginning of the season of 1915-16, the reports showed the holdings in each State. Later in that season it was decided to adopt a more convenient and probably more valuable grouping, and the reports are now issued showing the holdings of sections. The sectional grouping as finally adopted is shown in the accompanying map (fig. 3).

Besides comparing the reports of the current month with those of the same month in the preceding year, a comparison is made between the holdings of the current month and the holdings on December 1. This is to show the percentage of the amount stored for the season

that still remains in the warehouses. The same comparison is also made for the previous year, which shows the relative movement from storage during the two years.

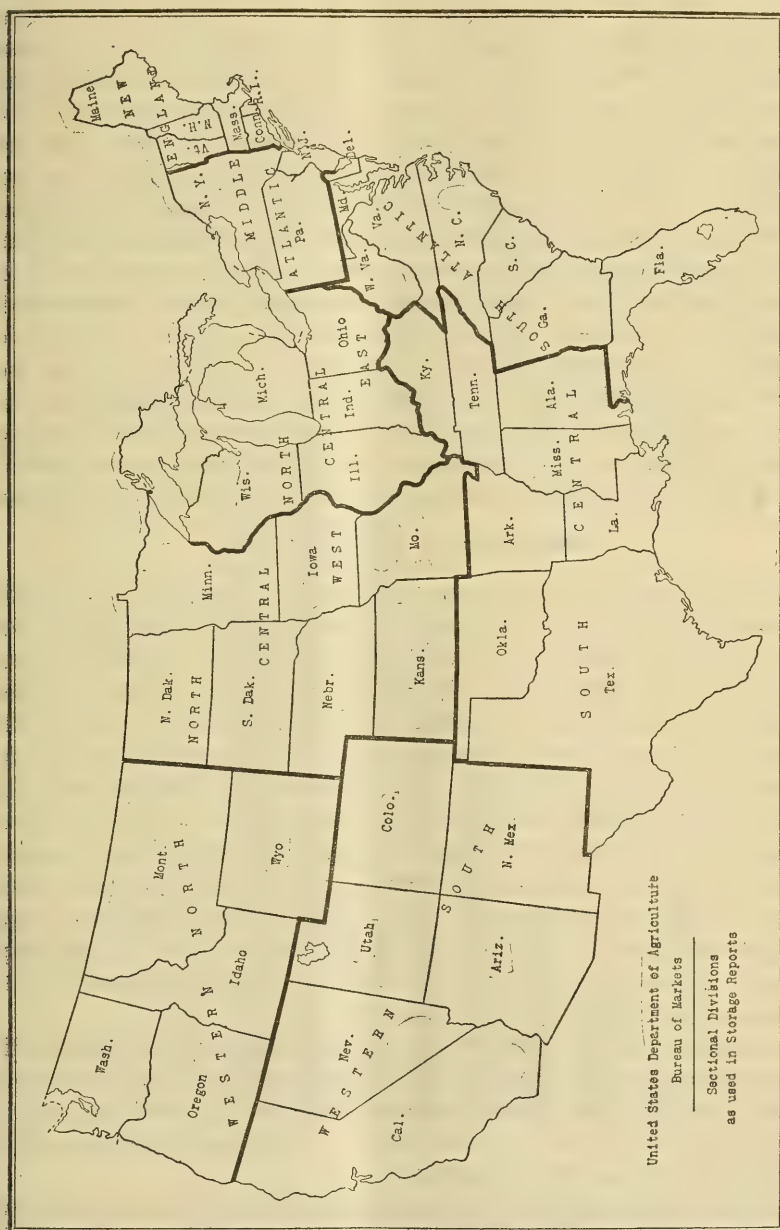


FIG. 3.

When the reports were extended to include the holdings of creamery butter, American cheese, and case eggs, the latter comparison was modified somewhat for these commodities. Instead of compar-

ing the holdings of the current month with the holdings of the maximum month, they are compared with the holdings of the preceding month, and the same comparison is made for the previous year. The comparison of the holdings of the current with the same month in the previous year is made for each section, while the comparison with the preceding month is made for the whole United States only. In comparing the holdings of any two months, the holdings of all firms not reporting for both months are eliminated from the comparisons. The reports of all commodities except fish show these comparisons and sectional divisions. The fish holdings are segregated into three sections only. The Atlantic section includes the New England, Middle, and South Atlantic States; the Western section includes Western North and Western South; all other States are included in the Central section. This seems to be the most logical grouping for reporting the storage of fish. It covers the three most important producing sections of the Atlantic coast, Pacific coast, and the Great Lakes. It does not differentiate between the Great Lake section and the Gulf of Mexico section, but as few fish are stored in the South Central States, this subdivision is considered unnecessary.

DISTRIBUTION OF THE INFORMATION.

A brief summary of the storage reports is furnished to the press through the Office of Information of the Department of Agriculture as soon as the returns are tabulated. Before it is released it is sent over the leased wires of the Bureau of Markets to its branch offices which are established in numerous cities throughout the United States. It is published in these offices at the same time that it is furnished to the press and press representatives in Washington. The value that the trade attaches to these reports is shown by the great demand for them and the prominence with which they are featured in the trade publications. Any person or firm not located in Washington or the cities in which branch offices are located may, upon application, receive the summaries or any part of them by telegraph, charges collect. Every effort is made to have these data reach all the interested parties at the same time.

As soon as possible after the information is compiled, the detailed reports are mimeographed and mailed. A copy of every report on all commodities is sent to each storage house on the mailing list. In addition to these firms, copies of any or all of the reports are sent to any person or firm requesting them.

When the first reports showing the holdings of apples in cold storage were issued, they were sent to a list, compiled from all available sources, of apple growers and dealers, and all of them were advised that the reports would be mailed to them regularly upon request.

C O L D S T O R A G E H O L D I N G S
O F
A P P L E S
Season 1916 - 1917

On December 1, 1916, 536 firms reported 2,845,075 barrels and 4,088,646 boxes or the equivalent of 4,207,957 barrels.) That amount is taken as 100 per cent in this diagram.

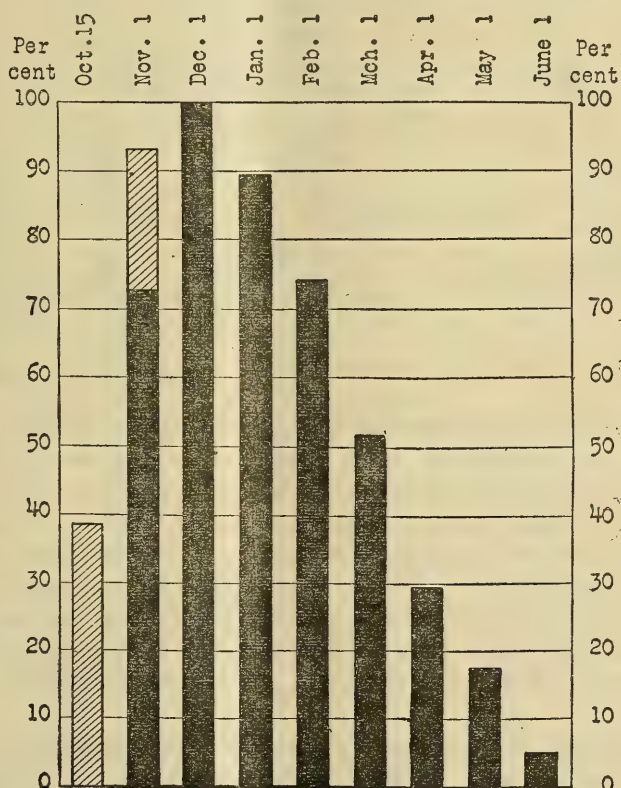


FIG. 4.

Copies were also sent to a selected list of trade papers and other publications.

As the work was extended to include other commodities, every effort was made to let the public know that the reports were available, free of cost, to anyone requesting them. Copies were sent to all dealers in these commodities in towns with a population of 25,000 or more and to a large list of producers. With the exception of the cold-storage warehouses, newspapers, trade publications, and certain Government officials, no reports are sent except upon request.

Approximately 75,000 copies of the reports for December, 1917, were mimeographed and mailed. Table 1 shows how they were distributed.

TABLE 1.—*Distribution of the storage reports of the Bureau of Markets on Dec. 1, 1917.*

Commodities.	Newspapers.	Storages.	Government officials.	By request.	Total.
Apples.....	3,500	1,444	600	3,401	8,945
Creamery butter.....	3,500	1,444	600	3,485	9,029
American cheese.....	3,500	1,444	600	2,707	8,251
Egg cases.....	3,500	1,444	600	3,832	9,376
Frozen eggs.....	3,500	1,444	600	3,832	9,376
Frozen and cured meats.....	3,500	1,444	600	2,262	7,806
Frozen poultry.....	3,500	1,444	600	1,705	7,249
Packing-stock butter.....	3,500	1,414	600	3,485	9,029
Frozen and cured fish.....	3,500	1,444	600	18	5,562
Total.....	31,500	12,996	5,400	24,727	74,623

REVIEW OF THE 1916-17 STORAGE SEASON FOR APPLES.

This season's reports began with a tabulation of the holdings in 352 storages on October 15, 1916. They showed a stock of 949,147 barrels and 1,062,564 boxes. This was 47.8 per cent less than was stored on October 15 of the previous season. Most of these holdings were probably stored after October 1 and amounted to more than one-third of the total quantity placed in storage during the season. By November 1 almost three-fourths of the holdings of the season had been stored. The balance of the holdings, with the exception of about 7 per cent, were stored before the 15th of November.

The holdings of December 1 represented practically all the apples stored for the season. In the 450 storages reporting they amounted to 2,603,584 barrels and 3,913,290 boxes. Three boxes are equivalent to about one barrel in quantity, so these storages held approximately 3,908,000 barrels. The boxed apples therefore represented one-third of the total holdings. In 1915 the boxed apples comprised one-fifth, and in 1914 one-fourth, of the total holdings.

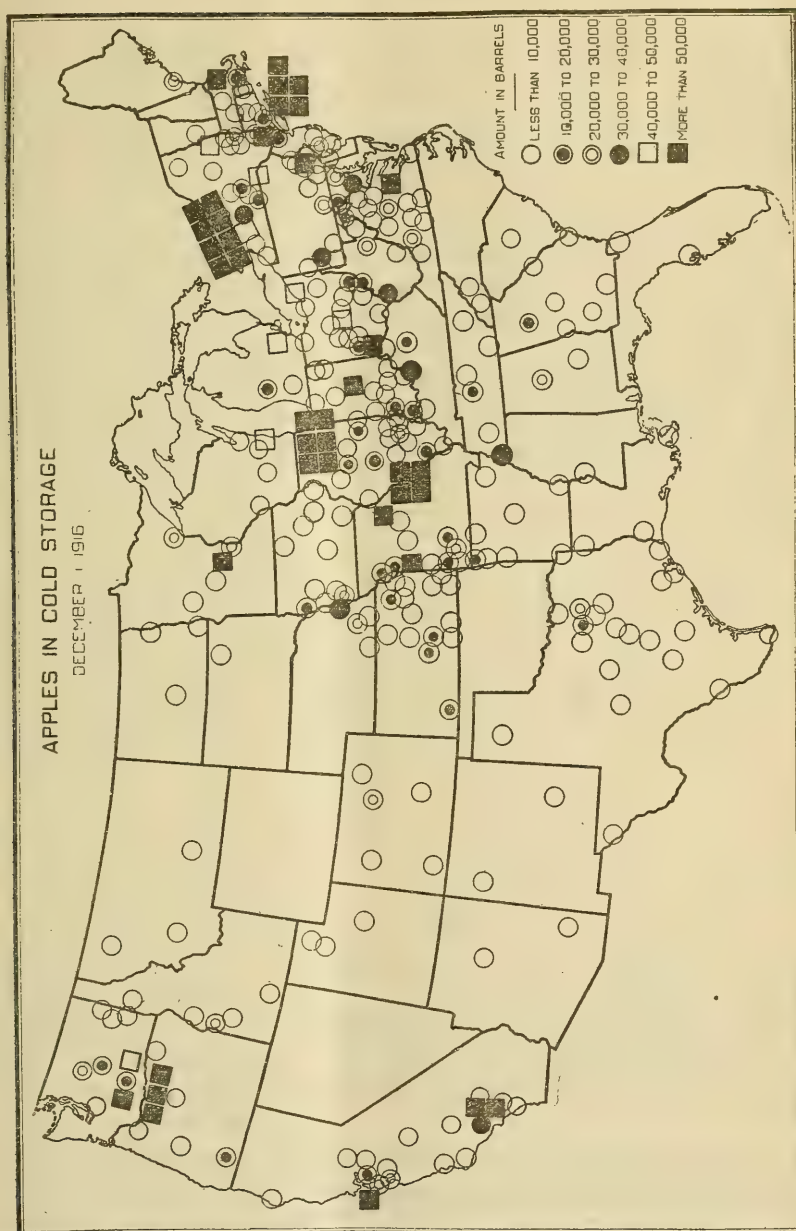


FIG. 5.

TABLE 2.—Cold-storage holdings of apples as reported on Dec. 1, 1916.

Section.	Storages reporting.	Barrels.	Boxes.	Combined.	Percentage in each section.
New England.....	13	112, 177	94, 418	143, 650	3.9
Middle Atlantic.....	88	1, 018, 620	523, 526	1, 193, 129	32.5
South Atlantic.....	31	180, 809	22, 174	188, 200	5.1
North Central (east).....	80	594, 800	284, 723	689, 708	18.8
North Central (west).....	59	364, 328	560, 140	551, 041	15.0
South Central.....	40	151, 208	209, 388	221, 004	6.0
Western (north).....	24	-----	1, 119, 996	373, 332	10.2
Western (south).....	32	12	929, 797	309, 944	8.5
Total.....	367	2, 421, 954	3, 744, 162	3, 670, 008	100.0

Table 2 shows the holdings of each section, the number of storages reporting, and the percentage relation of each section's holdings to the total amount stored on December 1. Figure 4 shows the distribution of the holdings graphically. The report shows that the distribution of the barreled apples was radically different from that of the boxed apples. Except for the great distributing centers of New York and Chicago, the holdings of boxed apples were generally confined to the

Western States, where apples are packed almost entirely in boxes. The great producing district of western New York stored an exceptionally large quantity of barreled apples locally. The proportionate quantity placed in cold storage there greatly exceeded that of the other producing sections.

The total quantity stored for this season was approximately one-third less than was stored the previous year, but the

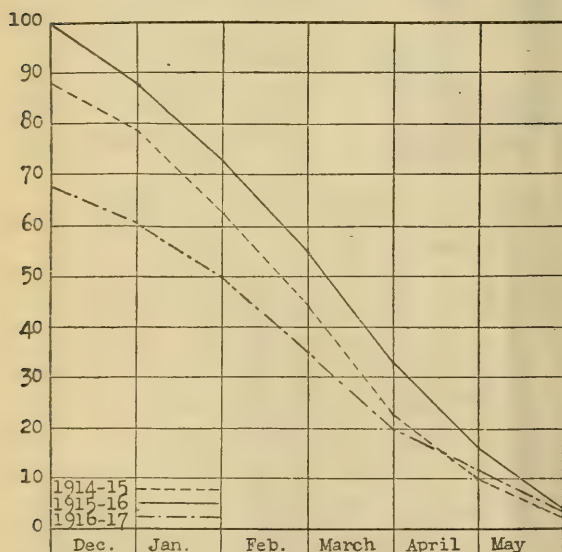


FIG. 6.—Comparative monthly holdings of apples in cold storage for the seasons of 1914-15, 1915-16, and 1916-17.

boxed-apple holdings showed a slight increase. The season's holdings were also one-fifth less than in the season of 1914-15. The relative holdings and movement from storage of those three years are shown in figures 5. Figure 6 shows the comparative holdings on the 1st day of each month during the season, the hatched portion of the diagram showing the relative holdings on the 15th of the month. More apples were distributed during February and March than in any other

month. The holdings were reduced 44.6 per cent in those months. The distribution of the barreled-apple stock began earlier in the season than that of the boxed apples. The month of December showed a movement of 15 per cent of the former compared with one-tenth of 1 per cent of the latter, a reduction of 10 per cent in the total holdings.

By June 1 the holdings had been reduced to 163,806 barrels and 221,122 boxes, or about 5 per cent of the total quantity stored. The percentage of the barreled apples remaining in storage was approximately the same as the percentage of the boxed apples still held. There was a larger percentage left in storage on June 1 than in the previous two seasons. June 1, 1916, showed 4.3 per cent left in storage and June 1, 1915, 1.9 per cent.

REVIEW OF THE 1916-17 COLD-STORAGE SEASON FOR BUTTER.

The largest holdings of creamery butter for this season were reported on September 1, 1916. The quantity in storage at that time represented practically the entire amount stored for the season by the warehouses reporting. The report covered 268 storages and showed a stock of 105,836,003 pounds. This was approximately the same quantity as was stored in the previous season, there being only a difference of two-thirds of 1 per cent. The accompanying tabulation (Table 3) shows the holdings on September 1, segregated by sections. Only a very small proportion, approximately 10 per cent, was stored outside of the New England, Middle Atlantic, and North Central States. Of the 29.4 per cent stored in the North Central section, east of the Mississippi River, 22.4 per cent was stored in the city of Chicago.

TABLE 3.—Cold-storage holdings of creamery butter as reported on Sept. 1, 1916.

Section.	Storages reporting.	Pounds.	Percentage in each section.
New England.....	19	25,908,623	24.5
Middle Atlantic.....	55	30,263,797	28.6
South Atlantic.....	24	1,429,666	1.4
North Central (east).....	46	31,133,057	29.4
North Central (west).....	50	9,132,755	8.6
South Central.....	25	1,345,638	1.2
Western (north).....	22	2,112,308	2.0
Western (south).....	27	4,510,159	4.3
Total.....	268	105,836,003	100.0

Figure 7 shows the comparative holdings on the 1st of each month throughout the season. At the beginning of the season, on May 1, there were a little more than a million pounds already in storage. This may be considered the carry-over from the preceding season and amounted to a little more than 1 per cent of the holdings of September 1. All but 5 per cent of the season's total holdings were

placed in the warehouses during the months of June and July. Reports were issued showing the holdings on June 15 and July 15. The

COLD STORAGE HOLDINGS
OF
CREAMERY BUTTER
Season 1916 - 1917

On September 1, 1916, 251 storages reported 105,235,506 pounds.
That amount is taken as 100 per cent in this diagram.

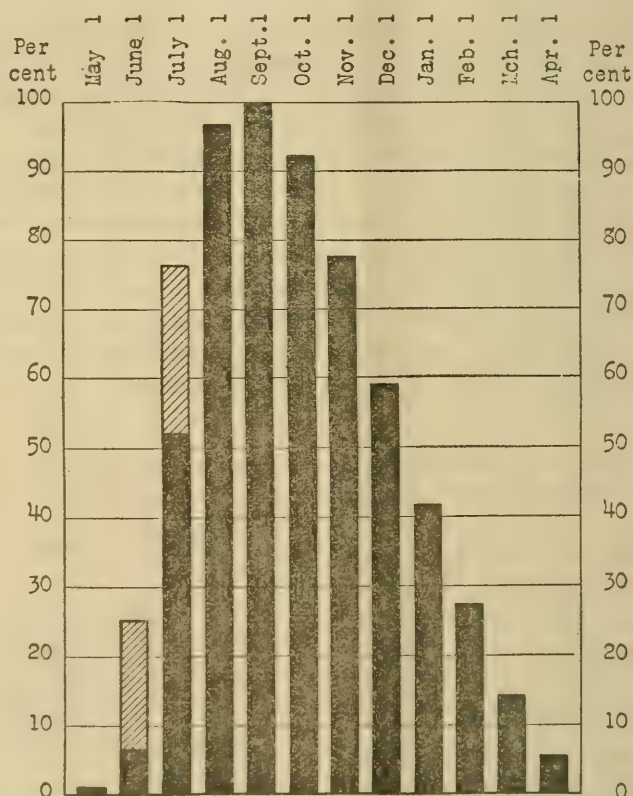


FIG. 7.

solid sections of the diagram indicate the relative holdings on the 1st of each month, while the hatched portions represent the relative in-

crease from the 1st to the 15th of that month. The distribution is quite evenly divided among the months of September to May, inclusive. It ranged from 18.6 per cent in November to 3.2 per cent in April. At the end of the season, on May 1, 1917, about 2½ per cent of the season's holdings still remained in storage, making a carry-over of twice the amount of the previous season.

TABLE 4.—*Monthly cold-storage holdings of creamery butter during the season of 1916 and 1917, and comparisons with holdings of preceding months.*

Date.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
June 1, 1916.....	173	6,760,071	1,064,464	+ 5,695,607	+535.1
July 1, 1916.....	173	52,576,210	6,782,641	+45,793,569	+675.2
Aug. 1, 1916.....	184	98,132,744	52,816,057	+45,316,687	+ 85.8
Sept. 1, 1916.....	233	104,950,786	101,606,527	+ 3,344,259	+ 3.3
Oct. 1, 1916.....	251	97,092,876	105,285,506	- 8,192,630	- 7.8
Nov. 1, 1916.....	303	83,248,135	98,758,024	-15,509,889	- 15.7
Dec. 1, 1916.....	293	64,632,056	83,687,857	-19,055,801	- 22.8
Jan. 1, 1917.....	248	42,787,367	60,377,710	-17,590,343	- 29.1
Feb. 1, 1917.....	249	29,982,089	45,753,022	-15,770,933	- 34.5
Mar. 1, 1917.....	257	15,467,475	29,808,296	-14,340,821	- 48.1
Apr. 1, 1917.....	265	6,208,763	15,679,464	- 9,470,701	- 60.4
May 1, 1917.....	252	2,553,912	6,046,958	- 3,493,046	- 57.8

The cold-storage holdings of packing-stock butter for December 1, 1917, are shown in Table No. 5, which also shows the relative amounts stored in each section. The distribution of this class of butter was radically different from that of creamery butter. The New England storages, which held almost one-fourth of the creamery butter, carried practically no packing-stock butter. The South Atlantic section, having only 1½ per cent of the creamery butter, carried almost one-fifth of the packing stock. The holdings of December 1, 1917, amounted to about three-fourths of the holdings of the previous year. The amount in storage on December 1 was approximately one-third of the total amount stored for the season.

TABLE 5.—*Cold-storage holdings of packing-stock butter as reported on Dec. 1, 1917.*

Section.	Total holdings Dec. 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percentage in each section.	Storages reporting.	Dec. 1, 1916.	Dec. 1, 1917.	Increase or decrease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	2	360	0.0	1	50	360	+620.0
Middle Atlantic.....	17	302,934	13.0	12	550,513	290,363	- 47.3
South Atlantic.....	12	423,575	18.2	9	141,687	368,301	+159.9
North Central (east).....	34	690,856	29.8	27	541,664	463,918	- 14.4
North Central (west).....	38	598,112	25.7	33	973,667	275,273	- 71.7
South Central.....	18	161,238	6.9	11	17,555	146,131	+732.4
Western (north).....	8	55,674	2.4	4	12,670	46,326	+265.6
Western (south).....	6	93,174	4.0	4	46,171	81,226	+ 75.9
Total.....	135	2,325,923	100.0	101	2,283,977	1,671,898	- 26.8

REVIEW OF THE 1916-17 COLD-STORAGE SEASON FOR AMERICAN CHEESE.

The Bureau of Markets began issuing reports on American cheese on September 1, 1916. This month's holdings represented practically the total quantities stored by the 290 storages which reported. They showed a total stock of 45,069,014 pounds, which was about 3 per cent less than the quantity stored in the previous season. However, this was the first report issued by the bureau regarding the stocks of this product, and the cooperation of all the cold-storage warehouses had not yet been secured; therefore this percentage may not be as accurate as the percentages secured in later reports.

The accompanying tabulation (Table 6) shows the holdings of September 1, segregated by sections, and the percentage of the holdings that were stored in each section. It will be observed that the Middle Atlantic States held 33.5 per cent of the total holdings. This section includes the great producing district of New York State and the holdings of the great distributing center of New York City. The producing district in the States of Wisconsin and Minnesota is divided between the sections of North Central east of the Mississippi River and North Central west of the Mississippi. The great difference between the holdings of these two sections is accounted for by the quantity held in Chicago, as the warehouses in that city held 16.7 per cent of the total holdings.

TABLE 6.—Cold-storage holdings of American cheese as reported on Sept. 1, 1916.

Section.	Storages reporting.	Pounds.	Percentage in each section.
New England.....	14	5,368,958	11.9
Middle Atlantic.....	66	19,619,664	43.5
South Atlantic.....	24	2,090,844	4.6
North Central (east).....	68	9,348,859	20.8
North Central (west).....	39	3,111,458	6.9
South Central.....	33	523,411	1.2
Western (north).....	19	917,671	2.0
Western (south).....	27	4,088,149	9.1
Total.....	290	45,069,014	100.0

The accompanying chart (fig. 8) shows the relative holdings on the first of each month during the season, using 100 per cent as the base representing the holdings of September 1. It shows that the cheese was placed in storage during the months of May, June, July, and August. More was stored during July than in any other month, about 40 per cent of the season's total holdings being placed in storage during that month. One-fourth of the holdings was stored during June and one-eighth during the month of August. The distribution of the stock extended over the months of September to April, inclusive,

varying from 3 to 23 per cent monthly. The month of April showed the most deliveries and the month of January the fewest.

COLD STORAGE HOLDINGS
OF
AMERICAN CHEESE
Season 1916 - 1917

On September 1, 1916, 273 storages reported 46,776,039 pounds.
That amount is taken as 100 per cent in this diagram.

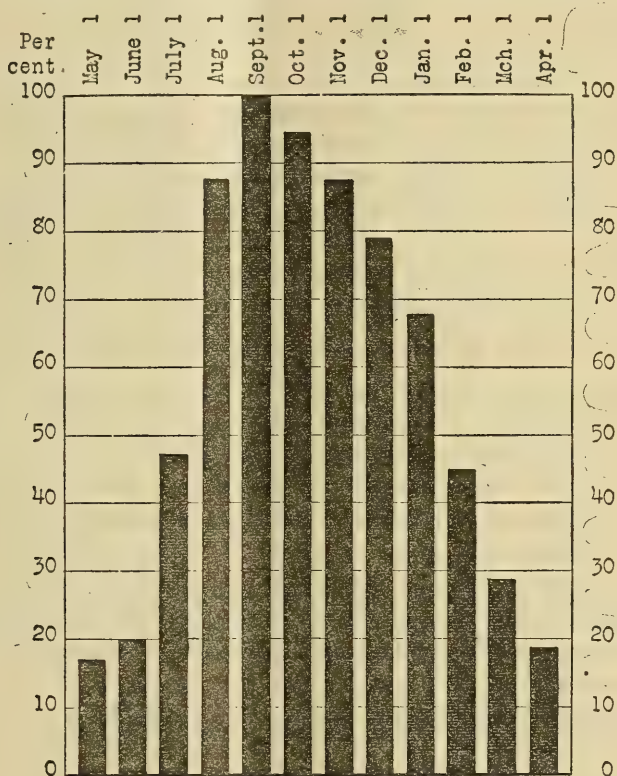


FIG. 8.

By April 1, the holdings had been reduced to 8,768,185 pounds, as reported by 347 firms. This was approximately 18½ per cent of the season's total holdings. An additional decrease of 8 per cent occurred

during the month of April, leaving 15 per cent in storage on May 1. The percentages of decrease, however, in the latter part of the season do not represent actual deliveries. The reports as published by the Bureau of Markets showed the holdings on the 1st of each month, and at this time some of the new stock was no doubt being placed in storage before all of the old stock was removed. The percentages, therefore, merely show the net decrease during those months. Table 7 shows the holdings of each month compared with those of the preceding month throughout the season, as published in the monthly reports of the bureau.

TABLE 7.—*Monthly cold-storage holdings of American cheese during the season of 1916 and 1917 and comparisons with holdings of preceding months.*

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
June 1, 1916.....	196	6,968,252	5,993,157	+ 975,095	+ 16.3
July 1, 1916.....	171	14,663,283	6,207,065	+ 8,456,218	+ 136.2
Aug. 1, 1916.....	183	30,512,859	16,432,758	+ 14,080,101	+ 85.7
Sept. 1, 1916.....	198	33,545,179	29,421,708	+ 4,123,471	+ 14.0
Oct. 1, 1916.....	273	44,308,627	46,776,039	- 2,467,412	- 5.3
Nov. 1, 1916.....	347	44,694,020	48,362,759	- 3,668,739	- 7.6
Dec. 1, 1916.....	212	31,833,373	37,569,742	- 5,736,369	- 15.3
Jan. 1, 1917.....	291	28,831,149	33,565,749	- 4,734,600	- 14.1
Feb. 1, 1917.....	282	19,789,865	29,934,336	- 10,144,471	- 33.9
Mar. 1, 1917.....	289	12,422,176	19,185,047	- 6,762,871	- 35.3
Apr. 1, 1917.....	321	8,506,087	13,329,133	- 4,823,046	- 36.2
May 1, 1917.....	309	6,969,562	8,411,022	- 1,441,460	- 17.1

REVIEW OF THE 1916-17 COLD-STORAGE SEASON FOR EGGS.

The cold-storage holdings of eggs reached their highest point on August 1. The 312 cold storages that reported held 6,060,129 cases of eggs on that date. The season's holdings were comparatively small, being only three-fourths as great as in the previous season. It should be considered, however, that an exceptionally large quantity was stored during the season of 1915-16. The distribution of the holdings is shown in Table 8. The warehouses in the Middle Atlantic and North Central sections held more than 80 per cent of the total. The major portion was held in the cities of New York, Philadelphia, and Chicago.

TABLE 8.—*Cold-storage holdings of case eggs as reported on Aug. 1, 1916.*

Section.	Storages reporting.	Cases.	Percentage in each section.
New England.....	15	569,542	9.4
Middle Atlantic.....	55	1,889,362	31.2
South Atlantic.....	16	74,299	1.2
North Central (east).....	62	1,943,574	32.1
North Central (west).....	70	1,082,026	17.8
South Central.....	38	133,744	2.2
Western (north).....	22	79,262	1.3
Western (south).....	34	288,320	4.8
Total.....	312	6,060,129	100.0

TABLE 9.—*Monthly cold-storage holdings of case eggs during the season 1916 and 1917, and comparison with holdings of preceding month.*

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Cases.</i>	<i>Per cent.</i>
April 1, 1916.....	212	182,706	34,439	+ 148,267	+430.5
May 1, 1916.....	233	2,269,851	261,257	+2,008,594	+708.8
June 1, 1916.....	236	4,493,350	2,353,332	+2,140,018	+ 90.9
July 1, 1916.....	224	5,440,704	4,485,255	+ 955,449	+ 21.3
Aug. 1, 1916.....	235	5,652,571	5,370,530	+ 282,041	+ 5.3
Sept. 1, 1916.....	296	5,437,412	6,064,623	- 627,211	- 10.3
Oct. 1, 1916.....	325	4,751,788	5,607,562	- 855,774	- 15.3
Nov. 1, 1916.....	364	3,577,956	4,789,945	-1,211,989	- 25.3
Dec. 1, 1916.....	374	2,108,969	3,543,636	-1,434,667	- 40.5
Jan. 1, 1917.....	272	896,826	2,089,344	-1,192,518	- 57.1
Feb. 1, 1917.....	264	146,141	897,642	- 751,501	- 13.7
March 1, 1917.....	260	4,100	144,257	- 140,157	- 97.2

Table 9 shows the monthly increase and decrease throughout the season, and figure 9 shows graphically the relative holdings on the first of each month, from April 1, 1916, to March 1, 1917. The solid portions of the diagram show the holdings on the first of the month, while the hatched portions under May and June show the increase from the 1st to the 15th of these months. All but about 10 per cent of the holdings were stored during April, May, and June, and practically all that were stored after June 15 were removed from storage before the 1st of September. Five per cent of the total holdings was already in storage on April 1. The monthly decreases of the season's total holdings were as follows:

	Per cent.		Per cent.
August.....	10.3	December.....	19.2
September.....	13.7	January.....	12.1
October.....	19.2	February.....	1.7
November.....	23.1		

A little more than one-tenth of 1 per cent still remained in storage on March 1, 1917.

TABLE 10.—*Cold-storage holdings of frozen eggs as reported on Sept. 1, 1917.*

Section.	Total holdings, Sept. 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percentage in each section.	Storages reporting.	Sept. 1, 1916.	Sept. 1, 1917.	Increase or decrease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	7	102,066	0.6	5	55,595	59,116	+ 6.3
Middle Atlantic.....	28	7,899,779	46.4	12	1,481,083	7,365,836	- 397.3
South Atlantic.....	7	148,162	.9				
North Central (east).....	36	4,137,173	24.3	24	2,372,730	3,178,399	- 34.0
North Central (west).....	40	3,787,404	22.3	30	999,437	3,436,913	+243.9
South Central.....	12	122,176	.7	8	14,083	50,866	+271.2
Western (north).....	9	266,672	1.6	6	140,059	90,176	- 35.6
Western (south).....	9	545,143	3.2	6	160,499	527,045	+228.4
Total.....	148	17,008,575	100.0	91	5,223,486	14,708,351	+181.6

The bureau began issuing reports showing the holdings of frozen eggs on May 1, and the holdings of September 1 were larger than for

C O L D S T O R A G E H O L D I N G S
O F
C A S E E G G S
Season 1916 - 1917.

On August 1, 1916, 235 storages reported 5,652,571 cases.

That amount is taken as 100 per cent in this diagram.

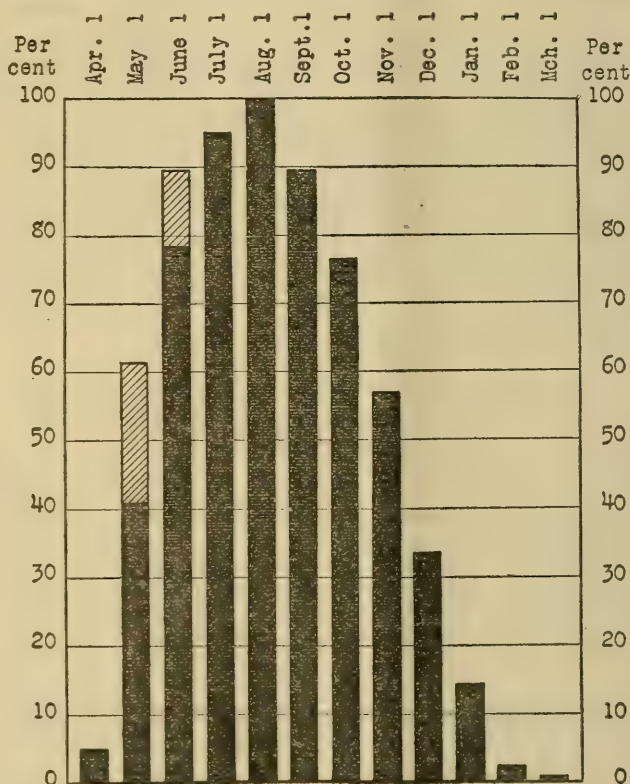


FIG. 9.

any other month during the season. Table 10 shows the holdings for that date, segregated by sections and compared with those on the

same date in the previous season. This comparison, based on the holdings of 91 cold-storage plants, showed an increase of more than 180 per cent over the previous year's stocks. Two-thirds of the stock were stored in the Middle Atlantic and North Central sections. The holdings decreased during the months of September, October, and November, but increased during December. The monthly decreases as indicated in the reports showed a very slow movement. As this product is largely used by bakeries and confectioners, its use was probably curtailed by the shortage of sugar.

REVIEW OF THE 1917 COLD-STORAGE HOLDINGS OF FROZEN AND CURED MEATS AND LARD.

The reports of the Bureau of Markets for the year 1917 showed the holdings and movement of approximately a billion pounds of frozen and cured meats and of lard. The commodities reported were frozen beef, pork, and lamb and mutton, cured beef, dry salt and sweet pickled pork, and lard. The maximum holdings during the year of the different commodities were as follows:

	Pounds.
Frozen beef, December 1.....	277, 284, 941
Cured beef, January 1.....	37, 301, 283
Frozen pork, August 1.....	94, 119, 901
Dry salt pork, March 1.....	249, 218, 917
Sweet pickled pork, July 1.....	412, 328, 689
Lard, August 1.....	111, 943, 363
Lamb and mutton, frozen, January 1.....	4, 885, 678

TABLE 11.—Cold-storage holdings of frozen beef as reported on Dec. 1, 1917.

Section.	Total holdings, Dec. 1, 1917.			Comparison with 1916.			
	Storages reporting.	* Pounds.	Percentage in each section.	Storages reporting.	Dec. 1, 1916.	Dec. 1, 1917.	Increase or decrease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	37	18, 229, 689	6.6	26	2, 681, 058	5, 886, 771	+119.6
Middle Atlantic.....	79	41, 229, 183	14.9	63	34, 407, 083	36, 866, 293	+ 7.1
South Atlantic.....	30	1, 516, 723	.6	25	1, 215, 160	1, 194, 098	- 1.7
North Central (east).....	75	147, 036, 771	53.0	64	83, 213, 567	141, 837, 668	+ 70.5
North Central (west).....	52	52, 053, 458	18.8	46	28, 926, 292	47, 884, 209	+ 65.5
South Central.....	29	6, 281, 454	2.2	21	4, 014, 663	5, 901, 801	+ 47.0
Western (north).....	25	6, 420, 835	2.3	22	1, 780, 058	4, 383, 245	+146.2
Western (south).....	34	4, 517, 828	1.6	30	1, 910, 123	4, 469, 464	+134.0
Total.....	361	277, 284, 941	100.0	297	158, 148, 004	248, 423, 549	+ 57.1

TABLE 12.—*Storage holdings of cured beef as reported on Dec. 1, 1917.*

Section.	Total holdings, Dec. 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percent- age in each section.	Storages reporting.	Dec. 1, 1916.	Dec. 1, 1917.	Increase or de- crease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	30	1,754,432	4.3	28	997,211	1,698,632	+ 70.3
Middle Atlantic.....	103	5,431,904	13.8	85	5,052,737	5,098,148	+ 0.9
South Atlantic.....	29	586,049	1.5	27	224,830	579,269	+157.7
North Central (east).....	95	17,700,741	44.9	85	18,379,308	17,571,286	- 4.4
North Central (west).....	40	12,393,969	31.4	38	12,552,700	12,296,694	- 2.0
South Central.....	17	545,597	1.4	13	238,213	513,433	+115.5
Western (north).....	23	458,888	1.2	19	151,156	393,604	+160.4
Western (south).....	24	588,175	1.5	23	361,431	578,175	+ 60.0
Total.....	361	39,459,755	100.0	318	37,957,586	38,729,271	+ 2.0

It will be observed that more than half of the frozen beef was stored in the North Central East section. Approximately 15 per cent was stored in the Middle Atlantic section and 19 per cent in the North Central West section. The sections of New England, South Atlantic, South Central, and Western North and South held only 13.3 per cent of the total holdings. These latter sections held approximately 10 per cent of the holdings of cured beef, approximately 45 per cent being stored in the North Central East and 3.4 in the North Central West section. Approximately 14 per cent was stored in the Middle Atlantic section.

TABLE 13.—*Cold-storage holdings of frozen pork as reported on Aug. 1, 1917.*

Section.	Total holdings Aug. 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percent- age in each section.	Storages reporting.	Aug. 1, 1916.	Aug. 1, 1917.	Increase or de- crease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	25	10,403,625	11.1	12	6,223,914	7,442,782	+19.6
Middle Atlantic.....	54	6,059,359	6.5	30	4,911,019	3,901,849	-20.5
South Atlantic.....	17	95,712	.1	7	2,000	16,000	+700.0
North Central (east).....	56	30,983,387	33.0	35	33,050,916	28,067,758	- 15.1
North Central (west).....	46	37,355,361	39.9	38	32,414,257	34,065,733	+ 5.1
South Central.....	20	2,759,438	2.9	13	3,446,281	2,203,379	- 36.1
Western (north).....	13	2,779,515	3.0	10	4,175,049	2,274,346	- 45.5
Western (south).....	22	3,248,013	3.5	15	1,621,745	2,047,658	+ 26.3
Total.....	253	93,684,410	100.0	160	85,845,181	80,019,555	- 6.8

TABLE 14.—*Storage holdings of dry salt pork as reported on Mar. 1, 1917.*

Section.	Total holdings Mar. 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percentage in each section.	Storages reporting.	Mar 1, 1916.	Mar. 1, 1917.	Increase or decrease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	17	8,694,867	3.5	9	7,577,496	7,487,092	- 1.2
Middle Atlantic.....	50	7,830,407	3.2	38	5,020,292	6,611,520	+31.7
South Atlantic.....	27	3,631,022	1.5	20	3,220,101	3,203,254	- 0.5
North Central (east).....	95	120,156,384	48.8	75	107,449,792	117,256,613	+ 9.1
North Central (west).....	67	92,345,743	37.5	61	88,086,420	92,136,180	+ 4.6
South Central.....	25	10,257,985	4.2	18	10,545,524	8,971,482	-14.9
Western (north).....	21	1,216,750	.5	19	2,306,014	1,216,078	-47.3
Western (south).....	20	2,058,024	.8	19	2,704,139	2,057,564	-23.9
Total.....	322	246,191,182	100.0	259	226,909,778	238,939,783	+ 5.3

TABLE 15.—*Storage holdings of sweet pickled pork as reported on July 1, 1917.*

Section.	Total holdings July 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percentage in each section.	Storages reporting.	July 1, 1916.	July 1, 1917.	Increase or decrease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	29	28,920,655	7.3	20	17,718,955	25,127,365	+41.8
Middle Atlantic.....	94	21,996,996	5.5	61	18,438,123	17,872,346	- 3.1
South Atlantic.....	35	5,302,610	1.3	24	5,384,016	4,666,784	-13.3
North Central (east).....	119	142,934,579	35.9	90	132,676,127	132,669,253	.....
North Central (west).....	64	162,468,814	40.8	55	152,093,076	157,841,343	+ 3.8
South Central.....	25	17,437,454	4.4	15	16,652,798	16,633,909	- 0.1
Western (north).....	38	7,284,811	1.8	24	8,788,283	5,607,954	-36.2
Western (south).....	31	11,985,003	3.0	24	7,558,808	10,273,067	+38.9
Total.....	430	398,380,922	100.0	313	359,300,186	370,692,021	+ 3.2

TABLE 16.—*Cold-storage holdings of lard as reported on July 1, 1917.*

Section.	Total holdings July 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percentage in each section.	Storages reporting.	July 1, 1916.	July 1, 1917.	Increase or decrease.
					<i>Pounds.</i>	<i>Pounds.</i>	<i>Per cent.</i>
New England.....	27	10,800,930	12.6	15	7,996,173	9,484,948	+18.6
Middle Atlantic.....	86	6,013,098	7.0	53	3,184,877	5,006,562	+57.2
South Atlantic.....	42	2,091,989	2.5	30	1,133,634	1,941,973	+71.3
North Central (east).....	112	38,504,135	45.0	82	51,814,861	35,926,976	-30.7
North Central (west).....	67	19,334,157	22.6	55	15,372,207	17,466,132	+13.6
South Central.....	37	2,342,484	2.7	19	2,359,834	2,095,273	-11.2
Western (north).....	31	2,654,212	3.1	23	2,552,013	2,006,149	-21.4
Western (south).....	32	3,826,563	4.5	25	2,713,776	3,776,078	+39.1
Total.....	434	85,567,568	100.0	307	87,127,375	77,704,091	-10.8

The holdings of frozen pork differed from the holdings of beef in that a much larger percentage was stored in the New England States. The North Central sections held almost 73 per cent of the

total holdings, the South Atlantic section having only one-tenth of 1 per cent. Only 13.7 per cent of the holdings of dry salt pork was stored outside of the North Central sections, nearly half of the total holdings being stored in the North Central East section. The holdings of sweet pickled pork were distributed in approximately the same proportions, a little more being stored in the New England and the Middle Atlantic sections. Approximately 73 per cent of the lard was stored in the North Central sections and 12.6 per cent in the New England section. The balance of the holdings was very evenly distributed among the other sections excepting the Middle Atlantic section, which held 7 per cent. A much larger proportion, 24.2 per cent, of the holdings of frozen lamb and mutton was held in the Middle Atlantic States; 60 per cent was stored in the North Central States, 6.3 per cent in the New England States, and 7.3 per cent in the South Central States. No firms in the South Atlantic States reported any holdings of frozen lamb and mutton on January 1, either for 1916 or 1917.

TABLE 17.—*Cold-storage holdings of frozen lamb and mutton as reported on January 1, 1917.*

Section.	Total holdings, Jan. 1, 1917.			Comparison with 1916.			
	Storages reporting.	Pounds.	Percentage in each section.	Storages reporting.	Jan. 1, 1916.	Jan. 1, 1917.	Increase or decrease.
New England.....	8	346,497	6.3	5	<i>Pounds.</i> 284,611	<i>Pounds.</i> 300,497	<i>Per cent.</i> + 5.6
Middle Atlantic.....	34	1,329,754	24.2	26	1,748,499	1,184,460	- 32.3
South Atlantic.....							
North Central (East).....	18	2,214,763	40.2	16	2,237,492	2,088,763	+ 6.6
North Central (West).....	19	1,089,515	19.8	18	408,166	1,089,465	+166.9
South Central.....	8	399,271	7.3	7	118,833	398,821	+235.6
Western (North).....	4	77,464	1.4	2	34,000	75,529	+122.1
Western (South).....	11	47,993	.8	10	143,927	47,697	- 66.9
Total.....	102	5,505,257	100.0	84	4,975,528	5,185,232	+ 4.2

Figures 10 to 16, inclusive, show the relative holdings on the 1st of each month during the year of 1917, and figures 17 to 23, inclusive, show the comparative holdings of the years 1916 and 1917.

The division between the holdings of each season is not nearly so clearly defined in the meat-storage reports as it is in the reports of the other commodities. The holdings of frozen beef reached their lowest point on June 1, when 39.8 per cent of the December 1 holdings were stored. On August 1, 63.9 per cent of the January 1 holdings were still in storage. The holdings of frozen pork reached a lower point than any of the other meat products, 27.5 per cent of the holdings of August 1 being held on December 1. Dry salt pork dropped down to 45.9 per cent and sweet pickled pork to 47.2 per cent on November 1. The lard holdings had a very rapid movement

in the latter part of the year. The maximum holdings of the year, which occurred on August 1, were decreased by two-thirds by Novem-

COLD STORAGE HOLDINGS
OF
FROZEN BEEF
1917

On December 1, 1917, 361 storages reported 277,284.941 pounds.
That amount is taken as 100 per cent in this diagram.

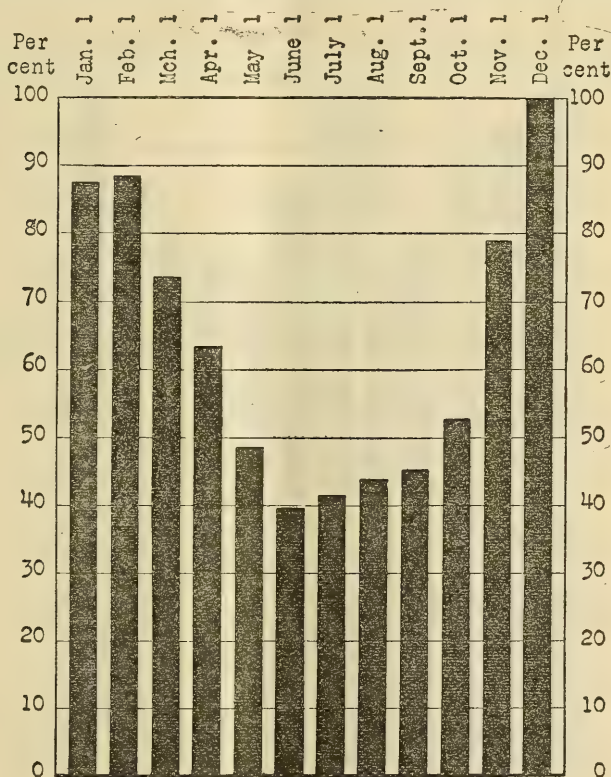


FIG. 10.

ber 1. The holdings of lamb and mutton, frozen, decreased from the maximum on January 1 to 37.1 per cent on June 1 and increased to 96.3 per cent on December 1.

STORAGE HOLDINGS
OF
CURED BEEF
1917

On January 1, 1917, 290 storages reported 37,301,283 pounds.
That amount is taken as 100 per cent in this diagram.

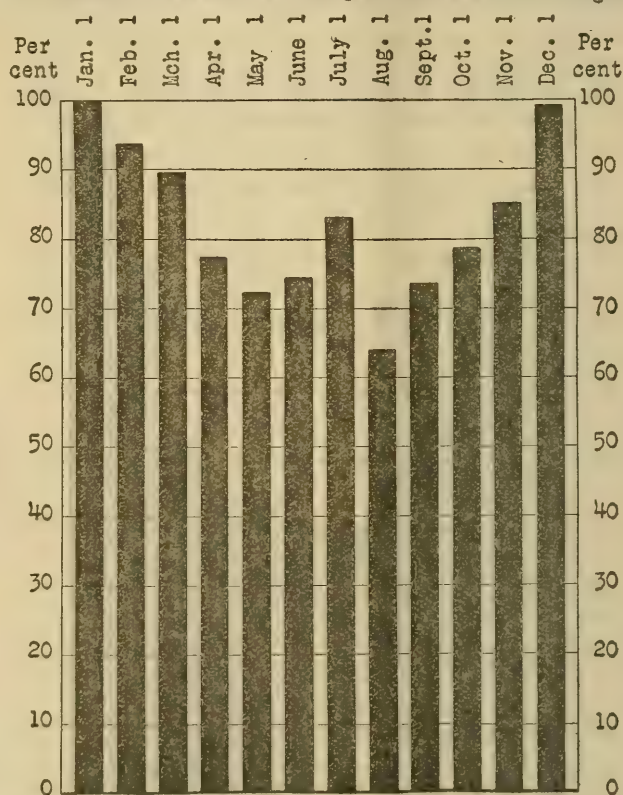


FIG. 11.

COLD STORAGE HOLDINGS
OF
FROZEN PORK
1917

On August 1, 1917, 264 storages reported 94,119,901 pounds.
That amount is taken as 100 per cent in this diagram.

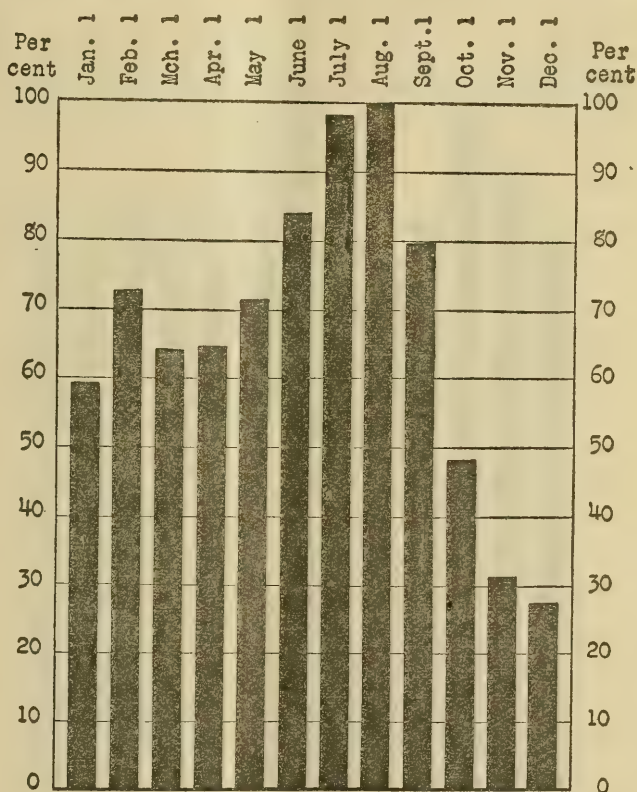


FIG. 12.

STORAGE HOLDINGS
OF
DRY SALT PORK
1917

On March 1, 1917, 233 storages reported 60,775,078 pounds.
That amount is taken as 100 per cent in this diagram.

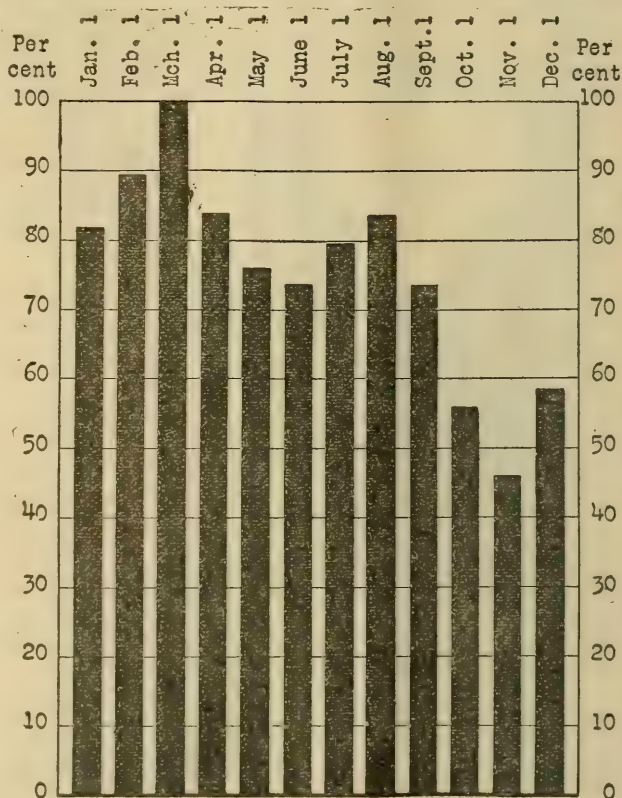


FIG. 13.

STORAGE HOLDINGS
OF
SWEET PICKLED PORK
1917

On July 1, 1917, 499 storages reported 412,328,689 pounds.
That amount is taken as 100 per cent in this diagram.

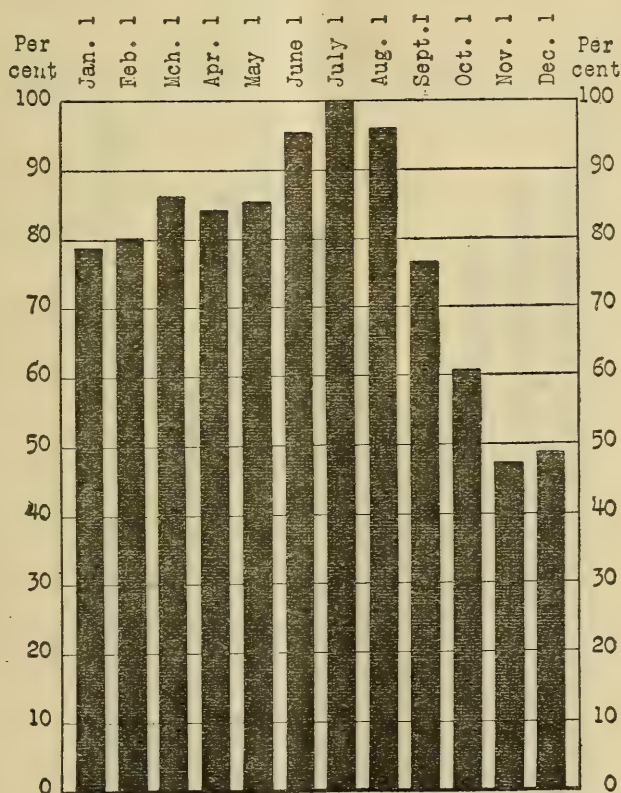


FIG. 14.

COLD STORAGE HOLDINGS OF LARD 1917

On August 1, 1917 500 storages reported 111,943,363 pounds.
That amount is taken as 100 per cent in this diagram.

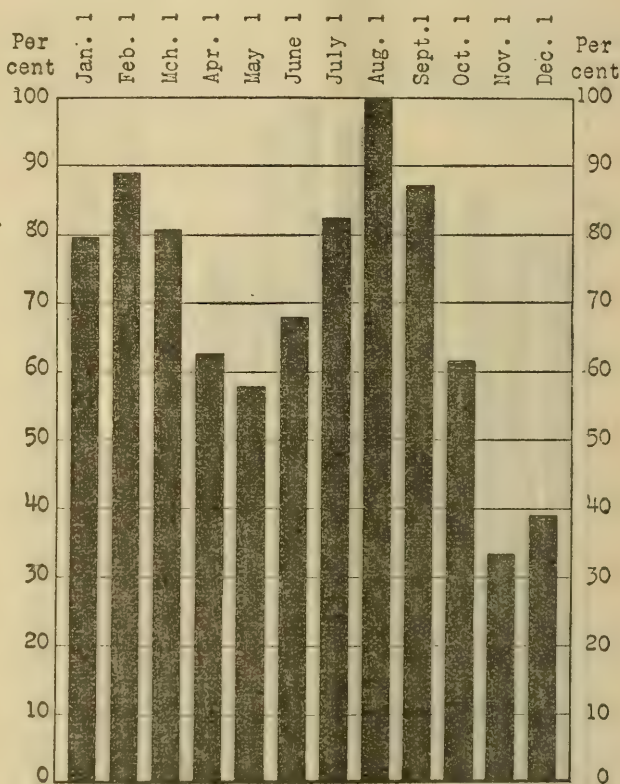


FIG. 15.

COLD STORAGE HOLDINGS
OF
LAMB AND MUTTON, FROZEN
1917

On January 1, 1917, 147 storages reported 4,885,678 pounds.
That amount is taken as 100 per cent in this diagram.

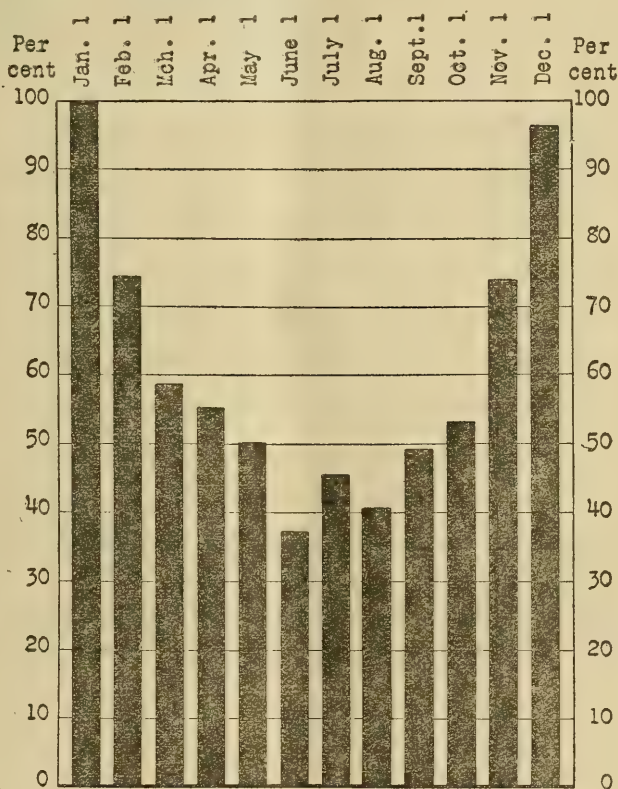


FIG. 16.

Tables 18 to 24 show the monthly holdings compared with the preceding months.

TABLE 18.—*Monthly cold-storage holdings of frozen beef during 1917, and comparison with holdings of preceding months.*

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
Jan. 1, 1917.....	156	162,081,360	125,594,410	+36,486,950	+29.1
Feb. 1, 1917.....	155	157,103,183	155,013,457	+2,089,726	+1.3
Mar. 1, 1917.....	220	157,201,985	188,482,010	-31,280,025	-16.6
Apr. 1, 1917.....	230	126,360,301	146,457,651	-20,097,350	-13.7
May 1, 1917.....	230	92,879,934	121,081,394	-28,201,460	-23.3
June 1, 1917.....	230	88,715,445	107,968,163	-19,252,718	-17.8
July 1, 1917.....	221	104,870,548	100,228,187	+4,642,361	+4.6
Aug. 1, 1917.....	244	112,112,800	105,797,385	+6,315,415	+6.0
Sept. 1, 1917.....	235	116,136,428	112,523,410	+3,613,018	+3.2
Oct. 1, 1917.....	244	136,716,841	116,355,167	+20,361,674	+17.5
Nov. 1, 1917.....	270	205,824,640	137,772,543	+68,052,097	+49.4
Dec. 1, 1917.....	307	266,126,640	210,224,765	+55,901,875	+26.6

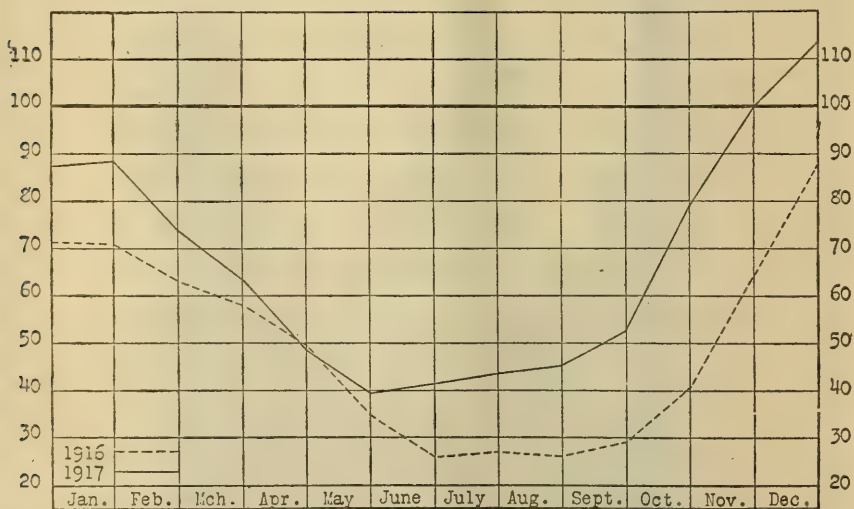


FIG. 17.—Relative monthly holdings of frozen beef during 1916 and 1917. Base, 100=holdings on December 1, 1917.

TABLE 19.—*Monthly storage holdings of cured beef during 1917, and comparison with holdings of preceding months.*

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
Jan. 1, 1917.....	181	38,439,174	47,428,995	-8,989,821	-19.0
Feb. 1, 1917.....	202	33,575,449	36,349,490	-2,774,041	-7.6
Mar. 1, 1917.....	233	36,728,363	39,062,781	-2,334,418	-6.0
Apr. 1, 1917.....	246	29,263,529	35,189,360	-5,925,831	-16.8
May 1, 1917.....	267	27,552,608	29,843,367	-2,290,759	-7.7
June 1, 1917.....	248	29,437,163	28,550,662	+ 886,501	+ 3.1
July 1, 1917.....	239	33,773,382	31,082,534	+2,690,848	+ 8.7
Aug. 1, 1917.....	243	25,060,046	28,420,259	-3,360,213	-11.8
Sept. 1, 1917.....	270	31,408,758	32,014,437	- 605,679	- 1.9
Oct. 1, 1917.....	276	32,364,729	30,954,458	+1,410,271	+ 4.6
Nov. 1, 1917.....	308	33,568,325	31,630,141	+1,938,184	+ 6.1
Dec. 1, 1917.....	320	38,276,227	33,465,310	+4,810,917	+14.4

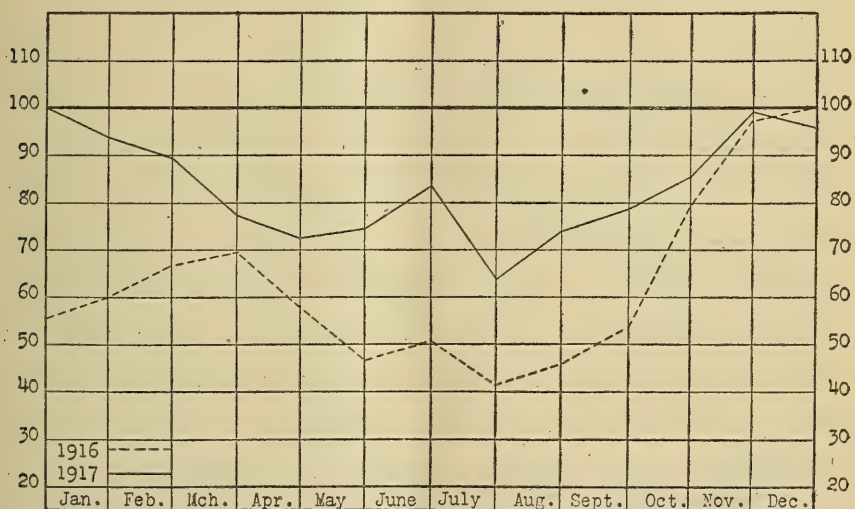


FIG. 18.—Relative monthly holdings of cured beef during 1916 and 1917. Base, 100=holdings on January 1, 1917.

TABLE 20—Monthly cold-storage holdings of frozen pork during 1917, and comparison with holdings of preceding months.

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
Jan. 1, 1917.....	120	45,648,436	29,075,909	+16,572,527	+57.0
Feb. 1, 1917.....	121	52,833,715	42,408,647	+10,425,068	+24.6
Mar. 1, 1917.....	153	49,948,393	55,888,174	- 5,939,781	-10.6
Apr. 1, 1917.....	213	58,550,569	58,193,351	+ 357,218	+ 0.6
May 1, 1917.....	218	60,392,987	54,732,728	+ 5,660,259	+10.3
June 1, 1917.....	209	75,616,850	64,229,455	+11,387,395	+17.7
July 1, 1917.....	206	89,491,716	76,590,121	+12,901,595	+16.8
Aug. 1, 1917.....	237	93,408,245	91,689,280	+ 1,718,965	+ 1.9
Sept. 1, 1917.....	221	74,634,527	93,388,898	-18,754,371	-20.1
Oct. 1, 1917.....	241	45,285,742	75,029,920	-29,744,178	-39.6
Nov. 1, 1917.....	249	28,735,326	44,309,260	-15,573,934	-35.1
Dec. 1, 1917.....	274	25,497,926	29,005,340	- 3,507,414	-12.1

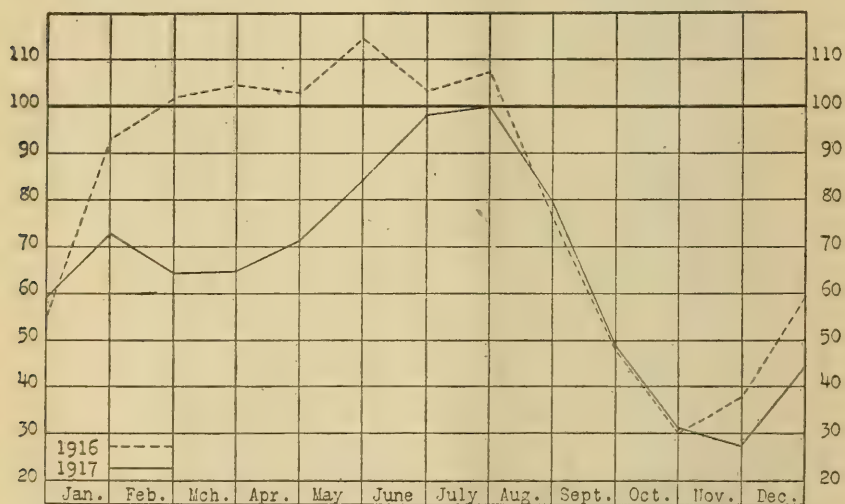


FIG. 19.—Relative monthly holdings of frozen pork during 1916 and 1917. Base, 100= holdings on August 1, 1917.

TABLE 21.—Monthly storage holdings of dry salt pork during 1917, and comparison with holdings of preceding months.

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
Jan. 1, 1917.....	246	184, 690, 987	129, 344, 996	+55, 345, 991	+42.8
Feb. 1, 1917.....	255	214, 604, 063	196, 247, 587	+18, 356, 476	+9.4
Mar. 1, 1917.....	303	243, 788, 560	218, 534, 515	+25, 254, 045	+11.6
Apr. 1, 1917.....	316	217, 594, 215	261, 736, 543	-44, 142, 328	-16.9
May 1, 1917.....	315	193, 164, 545	215, 792, 160	-22, 627, 615	-10.5
June 1, 1917.....	310	190, 630, 435	198, 483, 381	-7, 852, 946	-4.0
July 1, 1917.....	320	211, 466, 840	197, 421, 385	+14, 045, 455	+7.1
Aug. 1, 1917.....	348	222, 173, 475	213, 607, 748	+8, 565, 727	+4.0
Sept. 1, 1917.....	352	197, 079, 394	227, 454, 392	-30, 374, 998	-13.4
Oct. 1, 1917.....	365	141, 623, 635	194, 386, 290	-52, 762, 655	-27.1
Nov. 1, 1917.....	369	111, 422, 361	141, 960, 556	-30, 538, 195	-21.5
Dec. 1, 1917.....	380	142, 046, 548	107, 784, 221	+34, 262, 327	+31.8

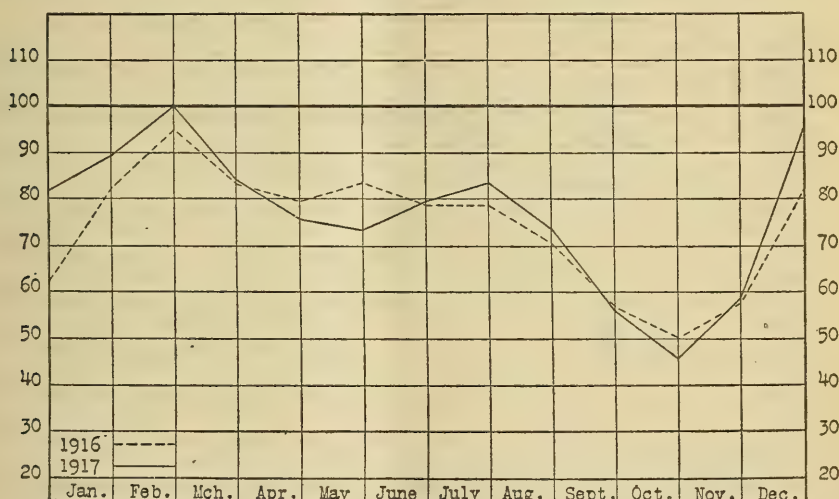


FIG. 20.—Relative monthly holdings of dry salt pork during 1916 and 1917. Base, 100—holdings on March 1, 1917.

TABLE 22.—*Monthly storage holdings of sweet pickled pork during 1917, and comparison with holdings of preceding months.*

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
Jan. 1, 1917.....	301	270,354,895	206,484,558	+63,870,337	+30.9
Feb. 1, 1917.....	325	316,264,836	277,434,589	+38,830,247	+14.0
Mar. 1, 1917.....	365	346,799,810	326,884,602	+19,915,208	+ 6.1
Apr. 1, 1917.....	388	322,128,168	333,329,204	-11,201,036	- 3.4
May 1, 1917.....	394	325,396,220	322,993,115	+ 2,403,105	+ 0.7
June 1, 1917.....	386	356,299,671	322,101,701	+34,197,970	+10.6
July 1, 1917.....	408	397,423,620	382,978,998	+14,444,622	+ 3.8
Aug. 1, 1917.....	439	385,653,657	401,956,728	-16,303,071	- 4.1
Sept. 1, 1917.....	453	315,792,117	395,811,819	-80,019,702	-20.2
Oct. 1, 1917.....	468	249,373,004	314,401,861	-65,028,857	-20.7
Nov. 1, 1917.....	480	194,188,681	249,914,993	-55,726,312	-22.3
Dec. 1, 1917.....	482	194,995,871	188,178,419	+ 6,817,452	+ 3.6

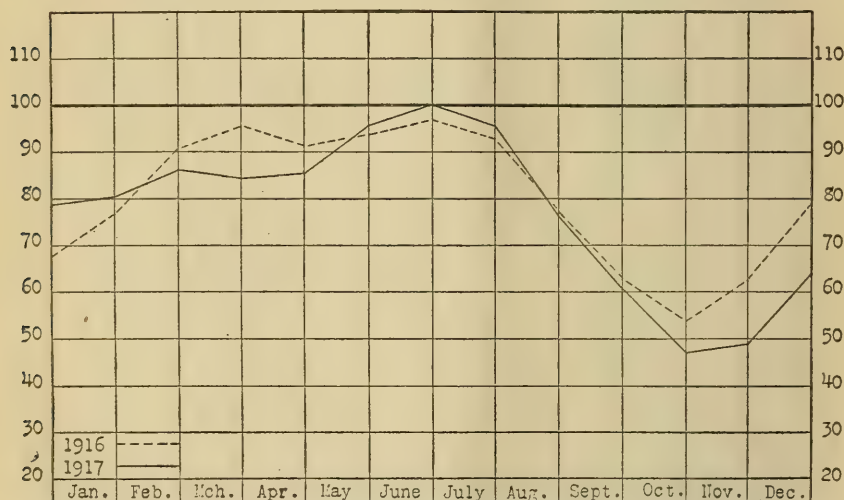


FIG. 21.—Relative monthly holdings of pickled pork during 1916 and 1917. Base, 100=holdings on July 1, 1917.

TABLE 23.—*Monthly cold-storage holdings of lard during 1917, and comparison with holdings of preceding months.*

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
Jan. 1, 1917.....	263	77, 140, 438	52, 140, 708	+24, 999, 730	+47.9
Feb. 1, 1917.....	299	86, 211, 628	81, 235, 587	+ 4, 976, 041	+ 6.1
Mar. 1, 1917.....	343	79, 394, 281	89, 448, 583	-10, 054, 302	-11.2
Apr. 1, 1917.....	351	60, 066, 401	77, 592, 709	-17, 526, 308	-22.6
May 1, 1917.....	355	55, 185, 864	59, 600, 542	- 4, 414, 678	- 7.4
June 1, 1917.....	340	62, 026, 824	52, 861, 556	+ 9, 165, 268	+17.3
July 1, 1917.....	382	84, 281, 922	69, 375, 077	+14, 906, 845	+21.5
Aug. 1, 1917.....	433	104, 126, 736	86, 003, 992	+18, 122, 744	+21.1
Sept. 1, 1917.....	450	96, 609, 408	110, 603, 562	-13, 994, 154	-12.7
Oct. 1, 1917.....	458	67, 841, 468	96, 520, 048	-28, 678, 580	-29.7
Nov. 1, 1917.....	477	37, 133, 757	68, 051, 027	-30, 917, 270	-45.4
Dec. 1, 1917.....	491	42, 810, 675	36, 767, 313	+ 6, 043, 362	+16.4

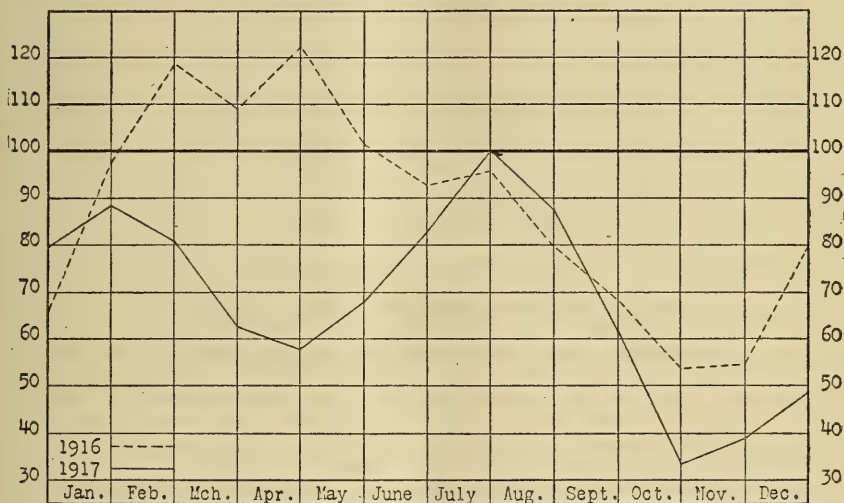


FIG. 22.—Relative monthly holdings of lard during 1916 and 1917. Base, 100=holdings on August 1, 1917.

TABLE 24.—*Monthly cold-storage holdings of frozen lamb and mutton during 1917, and comparison with holdings of preceding months.*

Month.	Storages reporting.	Comparative holdings.		Increase or decrease.	
		Current month.	Preceding month.		
				<i>Pounds.</i>	<i>Per cent.</i>
Jan. 1, 1917.....	87	4,926,526	4,716,108	+ 210,418	+ 4.5
Feb. 1, 1917.....	96	4,103,243	5,529,321	-1,426,078	-25.8
Mar. 1, 1917.....	112	4,685,029	5,926,100	-1,241,071	-20.9
Apr. 1, 1917.....	128	4,533,649	4,833,390	- 299,741	- 6.2
May 1, 1917.....	134	4,298,097	4,729,732	- 431,635	- 9.1
June 1, 1917.....	111	3,331,608	4,503,674	-1,172,066	-26.0
July 1, 1917.....	107	3,992,684	3,262,198	+ 730,486	+22.4
Aug. 1, 1917.....	127	3,560,485	3,977,137	- 416,652	-10.5
Sept. 1, 1917.....	129	2,892,120	3,598,771	- 706,651	-19.6
Oct. 1, 1917.....	137	3,152,313	2,913,215	+ 239,098	+ 8.0
Nov. 1, 1917.....	153	4,609,309	3,315,776	+1,293,533	+39.0
Dec. 1, 1917.....	158	6,072,665	4,661,257	+1,411,408	+30.3

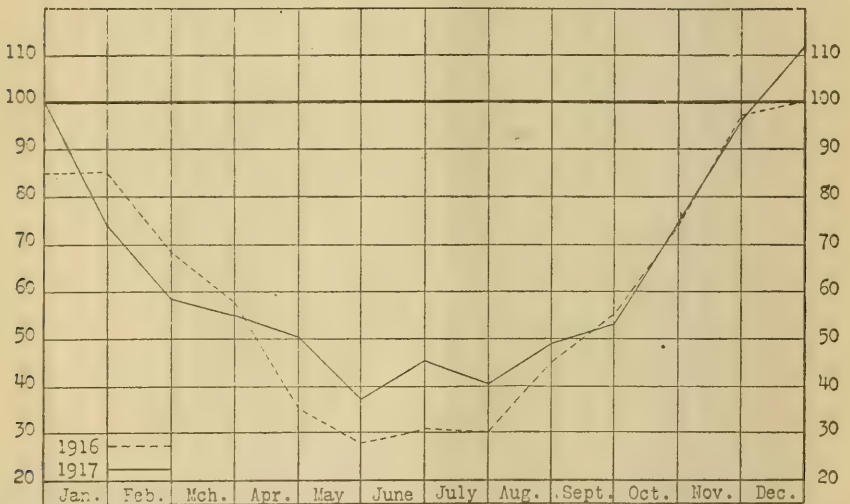


FIG. 23.—Relative monthly holdings of lamb and mutton, frozen, during 1916 and 1917. Base, 100=holdings on January 1, 1917.

Considerable difficulty was encountered in obtaining reports of the 1916 holdings of frozen and cured meats. In asking for data showing the holdings of each month during 1917, the storages were also requested to report amounts held on the same date in the previous year. Some of the figures reported were estimates, and the curve on the charts showing the holdings of 1916 should be considered as showing the general trend of the movement and not exact percentages.

STORAGE HOLDINGS OF FISH, DECEMBER 15, 1917.

Table 25 shows the holdings of fish as reported on December 15, 1917, segregated into the different sections. These reports have not been received for a sufficient number of months to indicate the movement into and out of storage.

TABLE 25.—*Holdings of fish reported Dec. 15, 1917.*

Varieties.	Atlantic.		Central.		Western.		Total.	
	Stor-ages.	Pounds.	Stor-ages.	Pounds.	Stor-ages.	Pounds.	Stor-ages.	Pounds.
Bluefish.....	15	156,192	23	20,652	1	.....	39	176,844
Butterfish.....	42	1,129,367	10	4,044	1	.....	53	1,133,411
Ciscoes.....	30	6,431,335	28	2,442,448	1	.....	59	8,873,783
Cod, hake, pollack..	40	4,001,193	42	248,917	11	403,443	93	4,653,553
Croakers.....	16	450,404	2	210	2	240	20	450,854
Halibut.....	26	984,052	50	920,775	23	5,139,715	99	7,044,542
Herring.....	46	4,109,796	43	3,745,902	7	101,612	101	7,957,310
Herring, cured.....	21	4,610,891	36	1,621,627	9	560,684	66	6,793,202
Lake trout.....	13	207,948	47	806,360	3	299	63	1,014,607
Mackerel.....	43	2,977,388	32	111,252	9	240,684	84	3,329,324
Rock fishes.....	3	16,898	4	61,520	6	30,752	13	109,170
Sablefish.....	4	4,207	21	196,485	16	1,650,664	41	1,851,356
Salmon, mild cured..	12	1,240,122	16	502,461	22	2,542,985	50	1,947,231
Salmon, fall.....	18	313,244	38	157,120	18	1,476,887	74	4,285,563
Salmon, silver.....	13	192,732	29	51,485	13	838,204	60	1,082,421
Salmon, other.....	16	190,968	24	122,718	22	995,195	62	1,308,881
Sea bass.....	22	327,645	11	20,190	5	13,299	38	361,134
Shad.....	35	285,478	16	173,851	11	57,136	62	516,465
Shad roe.....	16	33,349	22	17,021	10	65,907	48	116,277
Smelts, etc.....	18	178,261	33	323,960	14	449,674	65	1,001,895
Squid.....	26	2,375,444	6	12,328	2	42	34	2,387,814
Weakfish.....	24	1,132,214	.....	.....	1	.....	25	1,132,214
Whitefish.....	16	328,289	57	1,281,796	2	.....	75	1,610,085
Whiting.....	45	10,602,850	36	260,976	2	92	83	10,863,918
Miscellaneous.....	53	3,945,706	66	4,823,326	23	1,024,640	142	9,793,672
Total.....	69	46,225,953	83	17,927,424	33	15,642,154	185	79,795,531

SELECTED LIST OF PUBLICATIONS ON COMMERCIAL HOLDINGS.

The following is a list of statistical publications issued by the United States Department of Agriculture on the commercial holdings of the food products discussed in this bulletin. The Bureau of Markets has continued to issue detailed monthly reports in mimeographed form covering the storage holdings since the close of the 1916-17 season. (See p. 12.) The holdings for May 1, 1918, and subsequent months have been given in summary form in the publication entitled "Food Surveys."

Bureau of Statistics. Bulletin 93: Cold-Storage Business Features. Reports of Warehouses. 1913.

Bureau of Statistics. Bulletin 101: Cold Storage and Prices. 1913.

Office of the Secretary. Circular 97: The Supply of Lard in the United States: Its Extent and Distribution on August 31, 1917. 1918.

Office of the Secretary. Circular 101: Commercial Stocks of Miscellaneous Animal Food Products in the United States on August 31, 1917: Hams, Bacon and Shoulders, Salt Pork, Salt Beef, Salt Fish, and Condensed Milk. 1918.

Bureau of Markets. Food Surveys—Vol. 1, no. 4: Commercial Stocks of Lard (January 1, 1918); Vol. 1, no. 7: Commercial Stocks of Dairy and Related Products (January 1, 1918); Vol. 1, no. 9: Commercial Stocks of Meat and Meat Products (January 1, 1918); Vol. 1, no. 10: Commercial Stocks of Fish (January 1, 1918); Vol. 2, no. 3: Commercial Stocks of Dairy and Related Products, Not Including Retail Stocks (July 1, 1918); Vol. 2, no. 6: Commercial Stocks of Lard, Not Including Retail Stocks (July 1, 1918); Vol. 2, no. 9: Commercial Stocks of Cured Meat and Fish, Not Including Retail Stocks (July 1, 1918). 1918.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 710



Contribution from the Bureau of Animal Industry
JOHN R. MOHLER, Chief

Washington, D. C.

PROFESSIONAL PAPER

September 13, 1918

STAGGER GRASS (*CHROSPERMA MUSCÆTOXICUM*) AS A POISONOUS PLANT.

By C. DWIGHT MARSH and A. B. CLAWSON, *Physiologists, Poisonous Plant Investigations*, and HADLEIGH MARSH, *Veterinary Inspector*.

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DESCRIPTION AND CHARACTERISTICS.

Chrosperma muscætoxicum, commonly known as "stagger grass," "fly poison," "crow poison," or "fall poison," shown in figures 1 and 2, belongs to the lily family. It grows from a coated bulb, and reaches a height of from $1\frac{1}{2}$ to 4 feet. The leaves are narrow and grasslike, those of the stem being few and short. The stem is much longer than the leaves and bears a dense raceme of flowers, which turn greenish with age. The fruit is red. The plant is found in sandy woods from Long Island to Florida and west as far as Arkansas. It is said to grow at an altitude of 4,000 feet in Virginia.

The plant was first brought to the attention of this department by Mr. F. L. Huggins, of Wilmington, N. C., in March, 1911. He sent specimens of the plant and reported that the people of that neighborhood knew it as "stagger grass," and said that it was fatal to sheep in 24 hours. He said also that many cattle had been sick and that some had died from its effects. The matter was deemed of sufficient importance to make an investigation of the locality where the losses had occurred. The locality is a typical plains region of eastern

North Carolina, with very sandy soil. The country is nearly flat and has numerous swamps, at a slightly lower level, which are known as bays. The soil of the swamps, of course, is more largely composed of decayed vegetable material than is true of the more elevated land. Locally such soil is known as sand-rock soil, by which apparently is meant a more or less ferruginous sand, which is somewhat compact. The *Chrosperma* in this neighborhood seemed to be mostly confined to



FIG. 1.—*Chrosperma muscatoxicum*; young plants in bud.

the sand-rock soil and was found most abundantly on the slopes of the bays. It did not appear to grow upon either the more elevated land or the wet land, but in the region intermediate between the two. It was found in patches, sometimes several square rods being covered very thickly with it. At the time of the first visit, April 2, 1911, it looked very much like grass, was from 4 to 6 inches in height, and was the most conspicuous green vegetation upon the surface. The bulbs

are only 2 or 3 inches below the surface, but it does not seem probable that any animal in grazing would pull them up. Inquiry of Mr. Huggins and other people developed a good many interesting facts in



FIG. 2.—*Chrosperma muscætoxicum*; mature plant in blossom.

regard to the losses of animals in the locality. It appeared that the losses were almost entirely confined to cattle, although it was said that sheep were also affected by it, and that mules and horses might be

poisoned. As a matter of fact, cattle run wild throughout the region, but horses are never turned loose and perhaps would not have an opportunity for getting hold of the plant. Pigs also run about wild, but are never known to be poisoned.

All the cases of poisoning occur early in the spring, doubtless owing to the fact that at that time the *Chrosperma* is the only green plant and consequently is attractive to a grazing animal. Just how extensive the losses were it was impossible to find out, but it appeared that some occurred every year and that the plant was recognized by the people of the neighborhood as particularly destructive to cattle. The subject was deemed of sufficient importance to demand a careful investigation, inasmuch as the plant grows somewhat widely and may be the cause of losses not only in North Carolina but in other States. Queries in regard to the poisonous properties of *Chrosperma* have come from other localities, but the only definite reports of losses of live stock have been from North Carolina.

HISTORICAL SUMMARY.

The original description of the plant under the name *Melanthium muscatoxicum* was by Walter,¹ in the *Flora Caroliniana*, in 1788. The plant has received a large number of names, the discussion of which belongs to the systematic botanist. By many botanists it is placed in the genus *Amianthium*. The name used in this paper is the one recognized by Britton and Brown in "Illustrated Flora of Northeastern North America."

Apparently very little has been published concerning the poisonous properties of this plant.

Elliott, 1817, says:

This plant is a narcotic poison, and is employed in some families for destroying the housefly. The bulbs are triturated and mixed with molasses or honey and the preparation is spread upon plates and placed in parts of the house most effected. The flies are soon attracted, and the poison takes effect while they are sipping it. They are perceived to stand unsteadily, totter, and fall supine. The flies, unless swept into a fire or otherwise destroyed, revive in the course of 24 hours.

This appears to be the earliest mention of the poisonous properties of the plant, although it is to be presumed from the specific name given that Walter knew of this use of the plant.

Mohr, 1890, states that the root is poisonous.

Chesnut, 1898, says that it "is sometimes eaten by cattle with fatal results. The hulls, when mashed up with molasses, are used to stupefy flies."

In the *National Standard Dispensatory*, second edition, 1909, page 914, is the statement that it "is the fly, crow, or fall poison of the United States Atlantic coast region. It is used as an insecticide, and is poisonous to birds."

¹A list of literature cited appears at the end of this paper.

Alsberg, 1912, writing of "The Toxic Action of *Amianthium muscatoxicum*," says:

This liliaceous plant contains a solid alkaloid which has not been obtained in crystalline form. The alkaloid is of extreme toxicity, producing death from respiratory paralysis. The effect on the circulation is less prominent than that on the respiratory center. Striped muscle is affected in such a way that fatigue, both by direct and indirect stimulation, is very much more rapid than normally. Relaxation is somewhat delayed, but no distinct veratrine effect was obtained, though the alkaloid in some respects resembles veratrine chemically.

Alsberg, 1914, says: "From a member of a closely related genus *Amianthium muscatoxicum*, a similar active principle was obtained in an impure state. Apparently many of the species of this group of lilies contain 'veratrine' alkaloids or alkaloids related to it."

While the plant is mentioned by other authors as "fly poison" or "crow poison," the few statements given above seem to comprise all that has been written of its poisonous properties.

EXPERIMENTAL FEEDING OF THE PLANT.

A number of experiments of feeding the plant to both cattle and sheep were made, a summary of which is given in the following table. The plant material used was obtained from Wilmington, N. C.

TABLE 1.—Summary of feeding experiments with *Chrosperma muscatoxicum*.

Animal.		Experimental feeding.				Severity of illness.	Remedy.	Result.
Designation.	Weight.	Date.	Weight of plant fed.	Pounds fed per stated weight of animal.	Part of plant fed.			
	Lbs.	1911.	Lbs.	Per 1,000 lbs.				
Cattle No. 122..	108	Apr. 13..	0.1540	1.43	Leaves.....	Not sick....		
Do.....	108	Apr. 14..	.0990	.91564	do.....	Sick for some hours	None.....	Recovery.
Do.....	108	Apr. 18..	.0880	.814	Roots.....	Not sick....		
Do.....	108	Apr. 19..	.0220	.2024	do.....	Slightly sick	None.....	Do.
Do.....	108	May 4..	.0836	.77	Leaves.....	do.....	do.....	Do.
Do.....	108	May 5..	.1914	1.77	do.....	Slightly sick May 6.	Caffeine sodiobenzoate.	Do.
		1914.						
Cattle No. 663..	240	Mar. 23..	.545	2.261	do.....	Very sick....	None.....	Do.
Do.....	240	Apr. 3..	.220	.917	Bulbs; fed in grain.	Salivated....	do.....	
				Per 100 lbs.				
Sheep No. 228..	72	Mar. 24..	.044	.061	Leaves; fed in rye.	Symptoms....	do.....	Do.
Do.....	72	Mar. 25..	.066	.092	Leaves; forced feeding.	Very sick....	do.....	Do.
Do.....	72	Apr. 3, 4..	.331	.460	do.....	do.....	do.....	Do.
Sheep No. 277..	98.5	May 26..	.110	.112	Leaves, stems, and flowers; drench.	Not sick....	do.....	
Sheep No. 280..	99	May 26..	.055	.056	do.....	do.....	do.....	
Sheep No. 261..	76	May 27..	.251	.330	Leaves; drench..	Death.....	do.....	
Sheep No. 283..	78.5 to 76.5	May 27..	.172	.219	do.....	Symptoms....	Raw oil and turpentine.	Do.

TYPICAL CASES.

CATTLE No. 122.

The experimental work with calf No. 122 may be considered as giving typical results of the poisoning of cattle. The calf was somewhat undersized and poor, and weighed 108 pounds.

The feeding of the *Chrosperma* was commenced April 13, 1911. On this date 70 grams of the leaves of the plant were fed without any resulting symptoms. The plant material was received about April 11, and had been kept in cold storage. On April 14 the calf ate 45 grams of the leaves. This feeding was commenced at 10.25 a. m.,

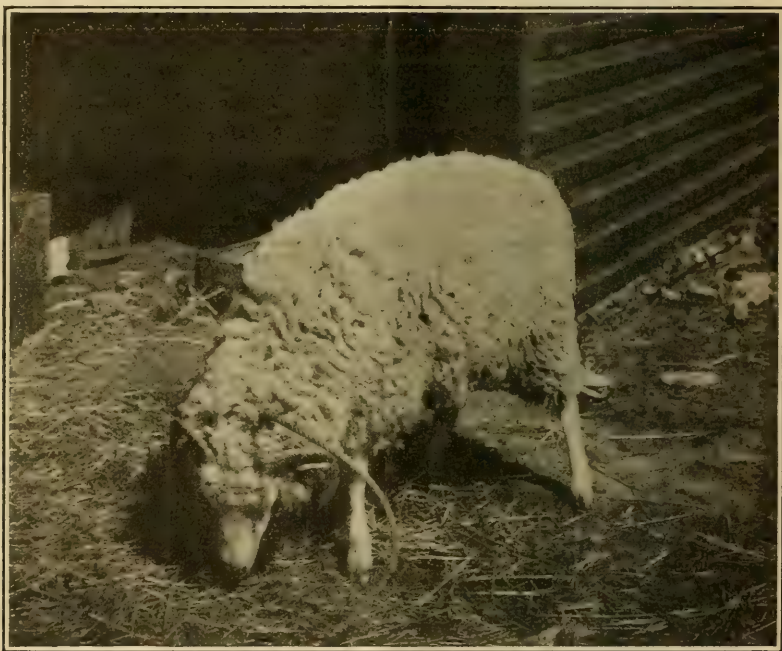


FIG. 3.—Sheep No. 228 at 1.14 p. m., March 25, 1914.

and at 11.40 the animal showed distinct signs of feeling ill. Her back was arched, she vomited, refusing to eat any more, and moaned. This condition continued until 12.06, and during this time the animal was quite sick. While lying down she threw her head sometimes from side to side and gave evidence of abdominal pain. After that there was less evidence of pain, but still much discomfort. The temperature was about normal. The animal appeared to be recovering and the observer left at 1.30 p. m. During the following night she was seen at intervals by the watchman, who reported that she vomited repeatedly. She staggered when walking, appearing to be especially weak in the hind parts. She did not recover her appetite until about noon, April 16. The effect of the poison apparently continued from April 14 to noon of April 16, or about 48 hours.

On April 18, at 11.30 a. m., experimental feeding was commenced again with the same animal. On that date she ate 40 grams of ground roots without any distinct symptoms of illness, and on April 19 she ate 10 grams. Between 12 and 2 p. m. on April 19 it was evident that she felt very uncomfortable. There was some constipation, although there was none on the preceding day. She was nauseated, but did not vomit, and would eat nothing. After 1 o'clock there was slight salivation.

On the succeeding day, April 20, she had entirely recovered, was eating grass, and the constipation had been relieved.



FIG. 4.—Sheep No. 228 at 4.30 p. m., April 4, 1914.

On May 4 feeding was commenced again, after 24 hours without feed. She ate 38 grams of leaves, the feeding commencing at 11.15 a. m. Between 3 and 4 p. m. there was distinct evidence of discomfort, and she ceased to eat, but there were no further symptoms of poisoning. The feeding was continued on May 5, when she ate 87 grams of the leaves. No symptoms appeared on that day, but on May 6, at 11 a. m., she was found to be breathing as if in discomfort and staggered when upon her feet. At 12 o'clock she groaned as if in pain, was constipated, and stopped eating entirely. There was some salivation. At 1.19 p. m. she was given 5 grains of caffeine sodiobenzoate. At 2 o'clock she appeared to be in good condition.

SHEEP No. 228.

The experiments with sheep No. 228 may be considered as typical of the effects of the plant upon sheep.

This sheep, a healthy ewe, weighing 72 pounds, was deprived of food on March 21 and 22, 1914, and on March 23 an attempt was made to make her eat the *Chrosperma*, which had been sent from North Carolina and had been kept in cold storage. As she would not take it, food was withheld for 24 hours longer. March 24, at 11.35 a. m., 10 grams of *Chrosperma* tops in green rye were given. At 11.41 a. m. another 10 grams mixed with rye were given. All this material was eaten in the course of the afternoon. On the morning



FIG. 5.—Sheep No. 228 at 10.25 a. m., April 5, 1914.

of March 25 the watchman reported that the sheep had been salivated during the night. She refused that morning to eat rye, but otherwise seemed to be all right.

At 10.25 a. m., March 25, 10 grams of the plant cut up fine and mixed with corn, oats, and wheat was offered, but very little was eaten, so that the material was fed by putting it directly into the sheep's mouth. Another 10 grams was given at 11.05 a. m., and a third 10 grams at 11.45 a. m. At 11.43 the ewe held her head low and shook it from side to side as if nauseated. At 11.45 there was distinct salivation, and at 12.05 vomiting. This condition of illness, representing nausea, extreme discomfort, and weakness, continued until between 2 and 2.30 p. m., at which time the sheep seemed to be very much better. Figure 3 shows the condition at 1.15 p. m.

March 26, 9.40 a. m., the sheep was lying down, but when made to get up staggered, licked her lips, and ground her teeth. She was weak and very much depressed but was able to stand. When walking the sheep was so weak that a slight pull upon a rope around the

horns caused her to fall over, and she would then not get up voluntarily, but if helped up would remain standing. The sheep was reported as having been very sick during the night. This condition of weakness continued during the day. On March 27 she was much better but still weak, and was eating nothing, but on March 28 she had practically recovered, and was in a normal condition.

April 3 the sheep, which had entirely recovered from the previous feeding, after having been deprived of food for 24 hours, was fed

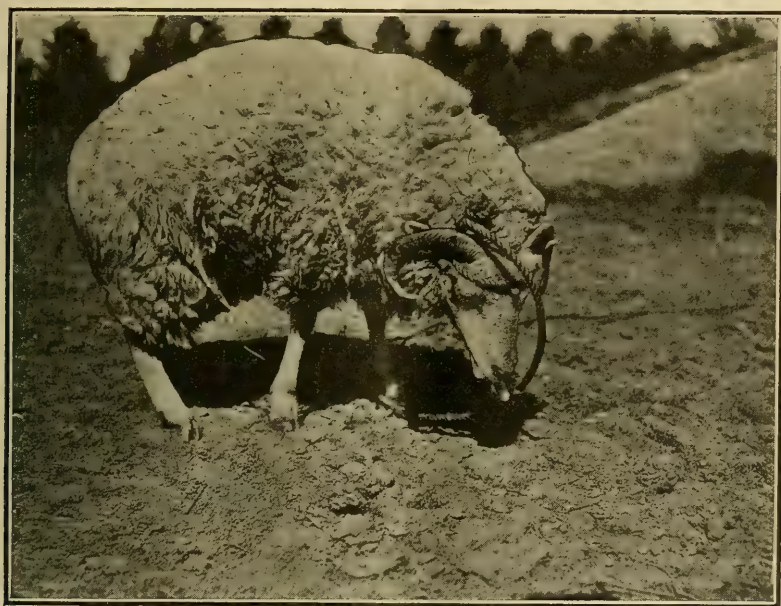


FIG. 6.—Sheep No. 228 at 9.35 a. m., April 6, 1914.

between 10.50 and 11.10 a. m. 100 grams of leaves of the *Chroserma*. This material was from the same collection as that used in the earlier experiments; it had been kept in cold storage and was in good condition. In this case the plant was fed by placing it, after it was cut up, directly into the back of the sheep's mouth, thus forcing the animal to swallow it, as she would not do so voluntarily. At 11.10 a. m. she was distinctly nauseated, and this condition continued marked for perhaps an hour, when the sheep seemed to be better, but was sleepy and listless. No marked symptoms were noticed until about 3 p. m., when vomiting commenced.

April 4, 9.30 a. m., the animal, lying down and apparently resting easily, was made to get up and walk about, when she showed that she was very weak, for she staggered when walking, and groaned. Figure 4 shows quite clearly an attitude indicating great weakness. As it was deemed best to carry the experiment farther, 50 grams of leaves, fed in the same way as before, were given between 10.50 and

10.55 a. m. During the remainder of the day there were no more pronounced symptoms, although the animal continued weak and evidently was in pain, as indicated by occasional groaning.

April 5, 10.25 a. m., the sheep was lying quietly in the pen, but when taken out proved to be very weak. She frothed at the mouth, grated the teeth, and while breathing groaned as though in pain. Figure 5 shows an attitude assumed at that time. There was no marked change in the condition of the animal during the day.

April 6, 9.35 a. m., the sheep appeared better and when taken out walked about but soon became weak and fell down with labored respiration, having great difficulty in getting her breath. Figure 6 shows the condition of the animal at the time. She was frothing at



FIG. 7.—Sheep No. 228 at 10.35 a. m., April 6, 1914.

the mouth and panting with very rapid respiration—about 200 a minute. Figure 7 shows the sheep an hour later, 10.35 a. m. The condition of the animal did not materially change during the day.

On April 7 when taken out of the pen the sheep staggered in attempting to walk, the legs being very weak. She breathed with gasps, was frothing at the mouth, pulse was 140, temperature 102. The illness was much more pronounced than on the preceding day.

On April 8 the sheep was very much better but still weak. Figure 8 shows very clearly the weak condition as it existed at 10.09 a. m. The animal was not frothing at the mouth, however, and showed a desire to eat. It was evident that she was recovering and that the trouble was mainly weakness. In order to get a complete record of

the case the sheep was killed and an autopsy made which showed nothing abnormal in the internal structures. Material of the liver, lung, kidney, and spleen was turned over to Dr. A. R. Ward, of the Pathological Division, Bureau of Animal Industry, who made the following report:

AUTOPSY ON SHEEP No. 228.

Liver.—The organ is normal to all intents and purposes. The hepatic cells took the staining well, and a good contact between the cytoplasm and karyoplasm is present in the well-marked lobules. There is no congestion, no inflammation, nor any cell proliferation of any kind. However, if we wish to be hypercritical, there appears a very slight, cloudy swelling with minute areas of serous fluid in the hepatic cells nearest to the capsule of Glisson.

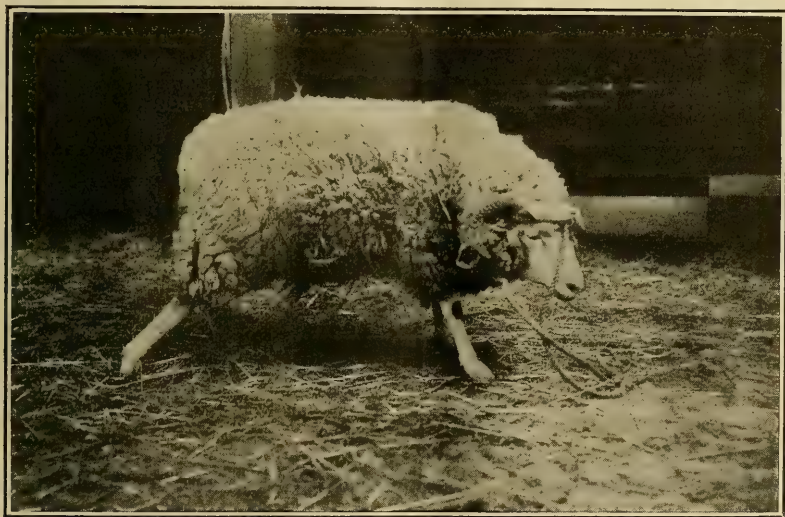


FIG. 8.—Sheep No. 228 at 10.09 a. m., April 8, 1914.

Lung.—Pleura thickened. Subendothelial capillaries prominent but empty. The air cells, infundibula, and pulmonary epithelium show no deviation from the normal. The smaller bronchial tubes are normal, but the larger ones show a slight peribronchial cell infiltration but no catarrh.

Kidney.—Capsule normal. Renal capillaries show no alteration except those constituting the glomeruli, which appear to be distended. There is a moderate number of red blood corpuscles which have passed into the capsule of Bowman. No parenchymatous and no interstitial changes are present.

Spleen.—Neither the splenic pulp nor the splenic corpuscles show any alteration. There is a small excess of hematogenous pigment, indicating that a number of red blood corpuscles have been disintegrated in the spleen.

GENERAL CONCLUSIONS.

TOXIC DOSE.

The only animals used for experimental purposes were cattle and sheep, and the number of experiments was too small to determine the dosage with any exactness. The fact that the symptoms sometimes

occur after a considerable delay also adds a doubtful factor to the determination of the dosage. The experiments with calf No. 122 in 1911 indicated that the toxic dose was not far from 1 gram, or 0.0022 pound, per pound of animal weight; or, put in another way, a 1,000-pound bovine would probably be poisoned by 2.2 pounds of the plant. The experiments with cattle in 1912 and 1914 served to confirm this general conclusion, and it seems probable that the toxic dose for a bovine weighing 1,000 pounds is not far from 2 pounds.

In the case of the sheep, symptoms were produced by 0.061 pound per 100 pounds of animal, and death was produced by 0.330 pound. Inasmuch as sheep No. 283 was sick and recovered from 0.219 pound, the lethal dose is somewhere between that figure and 0.330 pound. The large dosage received by sheep No. 228 on April 3 and 4 was distributed over two days with consequently less effect. In general, while too much reliance must not be placed on the results of a few experiments, it may be said that sheep may be poisoned by 0.06 pound, and fatal results may occur from a quantity between one-quarter and one-half of a pound. It will be noticed that, in terms of a ratio to body weight, the dosage for cattle and sheep is very nearly the same.

While the number of cases is small and there are a number of factors that throw doubt on the results, such as the varying conditions of the animals, the varying length of time in the feedings, etc., nevertheless the results may be considered as indicating approximately both the toxic and the lethal dose.

It appears to be probable from these experiments that *Chrosperma* is much more poisonous than the *Zygadenus* which causes such heavy losses of sheep in the West.

SYMPTOMS.

Salivation.—This is the first symptom noticed. The animal ceases eating and there is frothing at the mouth in a marked degree.

Nausea.—There are pronounced symptoms of nausea, which is followed in severe cases by profuse vomiting.

Pulse.—The pulse during most of the illness is nearly normal, although it may be somewhat rapid in the more acute stages of the intoxication.

Respiration.—The respiration is rather more rapid than normal and is frequently labored and irregular.

Temperature.—There is not much change in temperature, but it is liable to be slightly lower than normal.

Weakness.—The animal becomes very weak and staggers when it attempts to walk. When walking it moves in a stiff-legged manner.

Autopsy.—The autopsy findings indicate that in the organs there is little change which can be considered typical of the disease.

POISON CUMULATIVE.

The toxic effect of *Chrosperma* in the drenched cases appeared very quickly; in the fatal case death occurred in one hour. In the fed cases, however, even when the feeding was done by hand and consequently took but a short period of time, the symptoms appeared after several hours. When the feeding was done in the forenoon the most pronounced symptoms did not appear until the latter part of the afternoon or in the night. They persisted, too, for a long time. In the cattle they continued for two days, and one of the sheep was not completely recovered at the end of six days.

From this persistence of the toxic effect it seems that the poison is somewhat cumulative. In the cases in which feeding was continued on the second day it is pretty clear that its effect was added to that of the first day's feeding.

It seems probable that the long-continued illness resulting from eating the *Chrosperma* is due not so much to the severity of the toxic effect as to the fact that probably the active principle is extracted and absorbed somewhat slowly. It is to be presumed that in the drenched cases, inasmuch as the leaves were ground up and mixed with water, the poisonous principle is partly extracted at the time of the feeding. Moreover, the material of which a drench is composed goes in large part directly to the fourth stomach and consequently is quickly absorbed.

ANIMALS SUSCEPTIBLE.

The experimental work was with cattle and sheep, both of which were shown to be susceptible to the poisonous effect of the plant. As is stated earlier in the paper it is said in North Carolina that horses and mules, but not swine, are poisoned. The plant is shown to be so very poisonous that it seems probable that most animals are affected if they eat it.

One case of a child eating it and barely surviving has been reported to the writers. It seems rather strange that no more human cases have been known, for it seems certain that it is a very dangerous plant.

REMEDIAL MEASURES.

Not much can be done in the way of medicinal remedies. Doubtless a purgative would aid in eliminating the toxic substances. Experimental work on the related plant, *Zygadenus*, indicates that little can be expected from strictly antidotal treatment. Almost all that can be done is to keep the animals quiet and wait for the effects of the poison to pass off. Inasmuch as the effects of the toxic substance may continue for 2 or 3 days, or even longer, rapid recovery must not be expected.

SUMMARY.

Chrosperma muscatoxicum has been recognized as poisonous, but has not previously been reported as a stock-poisoning plant.

The plant has been known locally, in parts of North Carolina, as dangerous to cattle and sheep.

Experimental work has confirmed the opinion of its poisonous properties, and has shown that it is an extremely toxic plant.

Inasmuch as the plant occurs from Long Island to Florida and as far west as Arkansas, it seems probable that it may cause losses of stock in many places besides those reported.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 711

Contribution from the Forest Service
HENRY S. GRAVES, Forester



Washington, D. C.

PROFESSIONAL PAPER

November 14, 1918

LOGGING IN THE DOUGLAS FIR REGION.

By WILLIAM H. GIBBONS, *Forest Examiner.*

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OBJECT.

To bring together in systematic and usable form the bulk of the information dealing with Douglas fir logging costs thus far acquired, so as to make it accessible, is the object of this publication. The subject is broad in scope and only the more important features of the Douglas fir sawlog operation, as a rule, are covered. Greatest emphasis is laid on costs,¹ especially costs about which not much written material is available.²

¹ Costs and wages throughout the bulletin are based on conditions prior to April, 1917.

² In preparing the publication the writer consulted freely many of the lumber trade journals, especially those of Oregon and Washington; the proceedings of the Pacific Logging Congress, which were particularly helpful; "Logging," by Bryant; "Logging and Lumbering," by Schenck; "Earth Work and Its Cost," by Gillette; and unpublished manuscripts.

Few of the drawings are original, most of them being taken from catalogues and lumber trade journals, especially the Timberman.

The author wishes to acknowledge his indebtedness to all who have aided in any way in the preparation of this work, particularly the following, who reviewed portions or all of the manuscript: J. D. Young, J. S. O'Gorman, Fred MacFarlane, J. P. Van Orsdel, James O'Hearn, H. W. Sessoms, and R. V. Vinnedge, managers or superintendents of logging operations; F. M. Duggan and E. I. Karr, managers of log scaling and grading bureaus; C. S. Martin, C. P. Cronk, S. A. Stamm, and R. H. Shotwell, logging engineers, operating companies; W. T. Andrews, C. H. Woodcock, L. A. Nelson, Austin Cary, and E. C. Erickson, timber sales, Forest Service.

THE REGION.

The Douglas fir region includes practically all of Oregon and Washington west of the Cascade Mountains and a large part of British Columbia. The portion included in the west of Oregon and Washington, which is the part particularly referred to in this publication, has a width of from 70 to 170 miles and a length of 500 miles, embracing approximately 54,000 square miles, or an area as large as the New England States with New Jersey added.

The region varies greatly in its topographical makeup. In every part of it there are valleys, rolling hills, high tablelands, rivers, lakes, and mountains. A considerable proportion is mountainous, especially the timbered areas.

While great diversity is found in topographic features, similarity in the timber, as to size and volume of stand, has resulted, speaking generally, in the use of uniform logging methods. For this reason it has not been necessary to any considerable extent to consider special methods in connection with particular sections.

Mild winters are characteristic, and logging may be continued throughout practically the entire year.

COMMERCIAL SPECIES.

Douglas fir, the principal tree, is one of the most important American woods. It was early shipped to different parts of the world for masts and spars, and was the first tree in the region to be manufactured into lumber on a large scale. It ranks second in the United States in point of production, being very extensively used in the building trades by the railroads in the form of car and bridge material, ties, and piling, and by many manufacturing plants. As a structural timber it is not surpassed, and for a long time it was most widely used and known in this capacity. Originally covering, in forests of great density and almost absolute purity, the greater part of the foothills and lower slopes of the Cascade Mountains and the Coast Range, it now comprises about 70 per cent of the standing timber in the region. It is a gigantic tree, under favorable conditions having a diameter of from 3 to 6 feet. Trees 8 or 10 feet in diameter are to be found.

Western red cedar is one of the most durable woods grown in this country. It was first utilized for shingles about 30 years ago, and now supplies the bulk of the shingles manufactured in the United States. In addition, it is extensively used for poles, piling, posts, and siding. Its commercial range in this region is roughly confined to western Washington and northwestern Oregon. It forms about 10 per cent of the stand in the Puget Sound country and about 2 per cent in northwestern Oregon. In the region of its greatest abundance and best growth it has a higher stumpage value than any of the species with which it is commonly associated.

Sitka spruce, being used extensively in the manufacture of aeroplanes, is attracting more than ordinary attention at present. Its chief assets are strength and lightness, and lack of color and odor. For these reasons it is of great value in box and cooperage manufacture. It ranks with cottonwood as the best pulpwood in the region. Spruce confines itself to the vicinity of the coast, extending only along arms of the ocean and the courses of streams.

Western hemlock ranks next to Douglas fir in point of quantity, comprising about 10 per cent of the timber in the region. It is not confined to the forests of any one portion. On the west slope of the Cascade Mountains and the east slope of the Olympics and Coast Range it occurs most commonly in stands in which Douglas fir is the principal species. Here the percentage of hemlock varies from 5 to 60 per cent of the stand. On the western slopes of the Olympic Mountains and the Coast Range it is found with Sitka spruce, western red cedar, and Douglas fir, at times forming more than half of the stand.

After a thorough trial, hemlock wood has been found to be of excellent character. Unfortunately, its merits are too little appreciated as yet, the result being a weak demand for hemlock lumber and relatively poor utilization of hemlock in the woods. Western hemlock is utilized for rough lumber, all the principal planing-mill products, many of the manufactured products, pulpwood, piles, posts, and ties. It ranks fourth in the region in point of production. As time goes on this species will be in increasing demand for pulpwood.

There are several other trees in the region that will ultimately prove of great commercial importance. Noble fir, for example, has been utilized to a small extent within the last few years. It is a mountain tree, which has long, clear boles that yield a high percentage of clear lumber.

AMOUNT AND OWNERSHIP OF TIMBER.

Though more than 90 per cent of the region is potential timberland, no such area was timbered when white men started to utilize the land in 1850. Insects, winds, and fires set by lightning had denuded a perceptible area, and the Indians kept a small portion burned over. At present, about 70 per cent of the productive area in Oregon and Washington is timbered. This timber, with that in parts of British Columbia, constitutes the finest body of general-purpose timber known to exist. Large trees rise to a height of from 175 to 250 feet, or even more, and form very dense forests, which yield from 25,000 to 60,000 board feet per acre, and occasionally as much as 100,000 feet. Small tracts frequently cut out more than this.

The ownership, acreage, and volume of the timber in western Oregon and Washington are given approximately in Table 1.

TABLE 1.—*Ownership, acreage, and volume of timber in western Oregon and Washington.*

Ownership.	Area.	Per cent of total timbered area.	Stand, billions of feet b. m.	Per cent of total stand.
	<i>Acres.</i>			
National forests.....	10,816,000	48—	162	22—
Privately owned.....	8,991,000	40+	450	61+
State and other Government land.....	1,000,000	4+	40	5+
In litigation.....	1,700,000	8—	85	12—
Total.....	22,507,000	100	737	100

LOGGING IN GENERAL.

INDEPENDENT LOGGERS.

To the general rule that logging and lumber manufacture are conducted as one business the condition in the Douglas fir region is a striking exception. Not far from 50 per cent of the timber is logged by operators engaged solely in logging, who cut their own timber and sell their logs in the open market. The independent logger gets out most of the timber delivered to the waters of Puget Sound and the Columbia River; and he is an important factor at Grays Harbor, but plays a relatively small part at Willapa Harbor. Whether he has a permanent place in the lumber industry of the region no one can confidently predict.

So far, independent logging has seemingly worked out well, both from the standpoint of the capital invested and from that of the service performed. The independent logger, devoting his entire time and talents to logging, finds it easier to be efficient. As he disposes of his logs in the open market, the size of his operation is not limited by the capacity of a mill. As soon as business conditions make operating unprofitable, the independent logger, as a rule, can shut down. With the possible exception of difficulty in disposing of low-grade logs, he is not at a disadvantage in any respect at present. The opening up of new tracts of timber on a large scale, however, would probably change conditions.

The percentage of timber logged by contract is small.

SIZE OF OPERATIONS.

Logging operations vary in size, their daily output ranging from 40,000 to 500,000 feet.

An operation may consist of one or several camps. In any case, however, the camps are near each other, have a common ownership, and are supervised by the same head.

A camp may be made up of one or more sides, a side consisting of the crew and machinery necessary to handle the logs from one yarding engine. Where a number of engines are found at a side, each side may constitute a camp. A camp may include as many as four sides when only one or two engines are used at a side. It is difficult to generalize regarding this matter.

The output of a side, varying as it does with the yarding output, ranges generally from 40,000 to 80,000 feet per day.

STEPS IN AN OPERATION.

Powerful steam machinery is the most prominent feature of the logging operations of the Douglas fir region. The timber is large, the ground rough, rugged, and covered with bushes, so that some form of power logging is necessary. Logging with animals is confined for the most part to the logging of ties, bolts, piles, and poles.

The investments in logging plants are strikingly large. At present more capital is invested for improvements and equipment in Pacific coast logging operations than in similar operations in any other region of the United States, taking output into consideration. Therefore operators have to plan their work a long time in advance and be conversant with the most approved methods, not to mention mastering the maze of details in any enterprise conducted on a large scale.

The work in every department is specialized, each requiring a few technically trained men and a large percentage of skilled workmen. This is made necessary by the size of the operations, the complexity of the methods and equipment used, and the timber-utilization problems encountered. Trees 6, 8, or 10 feet in diameter, standing on rough, steep ground, are felled and converted into logs in such a way that a minimum of waste results; and logs, some of them scaling 10,000 board feet and weighing 30 tons, are dragged with great dispatch over the ground or swung down steep slopes and over deep canyons on overhead cables.

The term "logging," as commonly used, covers all the work of handling logs from standing timber to the sawmill. It can be divided into several steps. These, as well as the methods and equipment used, are not always distinctive, so that the subject is very involved and a classified treatment is essential. In this bulletin each step is treated separately in the order in which it occurs, which is as follows:

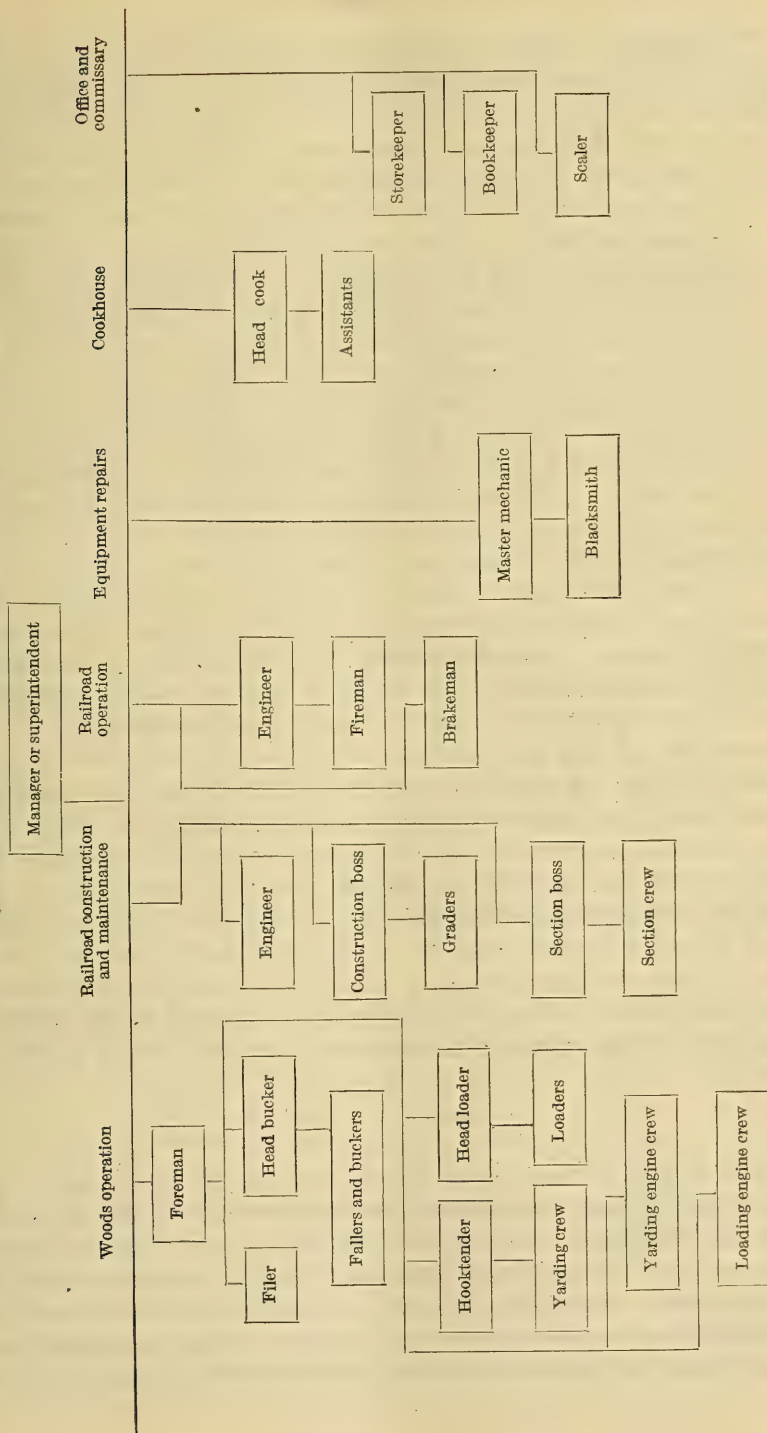
1. Felling and bucking.
2. Yarding, swinging, and roading.
3. Loading.
4. Railroad transportation.

ORGANIZATION OF THE PERSONNEL.

In the large operations a manager or logging superintendent, who spends all or a part of his time in the woods, is responsible for the logging and, if the operation is an independent one, for the sale of the logs. The camp foreman is next in responsibility. He may supervise directly all the different departments of the operation or just the work of delivering the logs to the landings. In some cases a logging engineer, responsible to the superintendent only, plans and constructs the railroads.

The usual division of responsibility is shown in the following diagram:

Organization of a Pacific coast logging operation.



LABOR.

The success of logging operations in this region depends in a large measure on the character, supply, and efficiency of the workmen; for the work is done under changing conditions, standardization of methods and output being to a great extent out of the question. Even under the most favorable conditions the skill, initiative, and reliability of most of the workmen count largely in the cost of logging.

On the other hand, the character and duration of the work and the conditions under which it is performed are not such as to attract, develop, and hold the type of workmen that logging operators hope to secure. The camps are in the woods; they usually afford very little opportunity for leading a normal life; and, with few exceptions, they do not satisfy certain normal and wholesome desires. The industry has to depend on a woods force composed in large part of restless, dissatisfied bachelors—old and young—largely foreign born, a large portion of whom constantly shift from camp to camp via the larger centers of population—men who are not in the way of doing the best for themselves or their employers.

This state of affairs, which is largely the logical consequence of our industrial and social development, is by no means confined to the logging industry. And the logging industry has not been slower than most industries to see that it does not pay; that even enlightened selfishness urges the bringing about of better conditions.

How to impress on the minds of the workmen the necessity and desirability of constant application and how to make the conditions as to hours, pay, and surroundings such as to induce the better workmen to continue with the industry, to attract desirable workmen from other fields, and the like, are difficult questions. A number of companies have attracted wide notice within the industry by remarkable and far-reaching provisions for the comfort, instruction, and recreation of their workmen, and by a mode and scale of payment enabling the employee to realize the largest earnings possible to his individual capacity. Most operators have modified former methods in some respects.

LENGTH OF EMPLOYMENT.

The length of time woods workers are required each year is governed by the methods of logging and the demand for logs or lumber. In the Douglas fir region many operators can continue logging throughout practically the entire year, and in no case for less than nine months. In recent years, however, the demand for forest products has been so weak that forest laborers in the region are fortunate when they secure seven or eight months' employment in a year.

No result of the depressed condition of the lumber industry is more deplorable than this. The short employment period each year and the peculiar social conditions are doubtless largely responsible for the fact that woods laborers of the region as a class are not as steady and efficient as they might be.

METHODS OF EMPLOYMENT AND PAYMENT.

There are three principal methods of hiring those of the men who are not hired directly by the camp foreman. The most common, perhaps, is through the regular employment agencies. Some of the larger operators employ their own agents. When a company uses enough men to justify the expense of a private agent, this usually proves the most satisfactory arrangement. In some instances several companies join in maintaining an agent, but that plan has often proved unsatisfactory because of a feeling that one company was favored more than another. In other cases the crews are kept up almost entirely from men who apply for work either at the camps or at the city offices.

So far labor unions have played only a small part in the logging industry of the region, and that in an indirect way. The natural independence of the woods worker and the fact that strong or normal demand for woods labor over long periods is unusual are probably the principal reasons why he has not affiliated with labor unions. Furthermore, living conditions in the camps are improving and relatively good wages are the rule. However, stronger efforts for the organization of a loggers' union are made each year.

Most of the men are paid by the day, the operators charging them for board. The monthly men, such as foreman, bookkeepers, cooks, and locomotive crews, as a rule, have their board in addition to their monthly wages.

Comparatively little contract work is done. In a few cases felling and bucking and railroad grading are contracted, and, less often, the delivery of the logs from the stump to the landing in the case of an out-of-the-way chance.

A system of bonuses, a modification of the wage system, is being tried out by a number of operators.

The men are usually paid once a month or on the termination of their work. Either bank or time checks are used. In most cases the time checks are taken at their face value by the merchants of the surrounding towns, the exception usually being in the town or city where the company has its offices and where the men may exchange the time or bank checks for cash.

WAGES.

The following is a list of the wages—average, high, and low—paid by logging companies on the west side of the Cascades in Oregon and Washington during the last six or eight years. The wages designated high and low do not represent extremes. For example, the wages paid at times during 1914 and 1915 averaged lower than those given in the list. Wages have remained at the same general level, rising or falling with fluctuations in the demand for labor. If there was any change, skilled labor received a little less toward the close of this period, common labor a little more. During slack times the wages of common labor are cut more heavily in proportion than those of skilled labor.

TABLE 2.—Average wages paid during the six years ending in 1916.

Position.	Wages per day.			Position.	Wages per day.		
	Average.	High.	Low.		Average.	High.	Low.
Head buckler or timber inspector.....	\$3.50	\$3.75	\$3.25	Master mechanic.....	\$4.50	\$5.00	\$3.00
Head faller.....	3.50	3.75	3.25	Carpenter.....	3.50	5.00	3.00
Second faller.....	3.25	3.50	3.00	Car tinkerer.....	3.00	3.25	2.75
Bucker.....	3.25	3.50	3.00	Pole road construction foreman.....	4.50	5.25	4.00
Filer.....	3.75	4.00	3.50	Pole road construction men.....	2.75	3.00	2.50
Hooktender.....	5.25	6.00	4.50	Landing construction foreman.....	4.00	4.50	3.50
Rigging slinger.....	3.50	3.75	3.25	Landing construction men.....	2.75	3.00	2.50
Chokerman.....	3.25	3.50	3.00	Locomotive engineer.....	4.00	4.50	3.75
Chaser.....	3.25	3.50	3.00	Locomotive fireman.....	3.00	3.25	2.75
Swamper.....	3.00	3.25	2.75	Conductor or head brakeman.....	3.50	4.00	3.25
Sniper.....	3.00	3.25	2.75	Brakeman.....	3.25	3.50	3.00
Signal man.....	2.75	3.00	2.50	Section foreman.....	3.25	3.50	3.00
Yarding and road engine engineer.....	3.50	3.75	3.25	Section men.....	2.50	2.75	2.25
Yarding and road engine fireman.....	2.50	2.75	2.25	Railroad construction foreman.....	4.50	5.50	3.50
Wood buck.....	2.50	2.75	2.25	Railroad construction men.....	2.50	2.75	2.25
Head loader.....	4.25	4.75	3.50	Rafting, or boom, foreman.....	3.50	4.00	3.25
Second loader.....	3.50	3.75	3.25	Rafting, or boom, man.....	3.25	3.50	3.00
Gypsy, or spool, tender.....	3.00	3.25	2.75				
Loading engine engineer.....	3.25	3.50	3.00				
Loading engine fireman.....	2.50	2.75	2.25				
Pump man.....	2.75	3.00	2.50				
Blacksmith.....	3.75	4.00	3.50				

Certain employees who, as a rule, are paid by the month are not included in the above list. The monthly salaries of these men are about as follows, plus board:

Foreman	\$125 to \$250
Bookkeeper.....	75 to 125
Timekeeper.....	75 to 100
Storekeeper.....	75 to 125
Logging engineer.....	75 to 125
Scaler.....	75 to 125

BOARD.

Operators in the region feel that a well-fed man gives better service and is more likely to be satisfied with his work, so that a well-conducted boarding department is one of the features of most operations.

The quality and variety of the food are of a high order. Fresh meats, vegetables in season, and canned fruits and vegetables of a good quality are to be found in practically all the camps. Wherever possible the men come in to all meals. A lunch in the woods occasions much grumbling.

Boarding departments, as a rule, are self-supporting, the weekly charge in 1916 amounting to \$5 or more. Cooks are paid from \$50 to \$150 per month, depending on the size of the crew. Camps of 60 men or more usually have an assistant cook, the kitchen help being figured on the basis of 1 man in the kitchen for each 30 men in the crew.

CAMPS.

It is good to be able to record that no greater advance has been made in any of the departments of the operation than in the housing and care of the workmen, and that the progressive loggers of the Pacific Northwest have been leaders in the industry of the whole country in providing model camps.

A few years ago camp buildings were crude structures, having few, if any, conveniences. Unfortunately, in many camps there is still much room for improvement. Fairly satisfactory living quarters, however, are the rule, the best camps being well constructed of dressed lumber and equipped with individual beds or bunks, private lockers for clothing, hot and cold water, steam heat, and like accommodations. Furthermore, camps of the latter class have a pleasing appearance, due regard being given to the design and arrangement of the buildings and the color of the paint used. Operators as a class do not seem to have given sufficient attention to camp sanitation.

Three types of camps are used, the portable camp on wheels, the portable camp on skids, and the stationary camp. All three prove satisfactory, and each is adapted to certain conditions.

(1) *Camp on wheels*.—Mr. C. S. Martin, who is employed as a logging engineer by one of the largest operators on the Pacific coast and who has had an opportunity to study the different methods of housing the men, discusses the modern complete camp on wheels as follows:

The advantages of camps on wheels are coming to be widely recognized. The first cost may be greater, but when one takes into consideration the following arguments in their favor it will be found that they prove cheaper in the long run, giving the camps a life of from 10 to 20 years, which is, I believe, conservative.

(a) *Insurance*.—In case of fire the camps can be moved at a few minutes' notice.

(b) *Depreciation*.—Ten per cent should cover both depreciation and upkeep, a much smaller percentage than had to be charged to the old shack camps, which cost nearly as much to tear down and rebuild as to abandon.

(c) *Wages and time saved in moving.*—We moved Camp No. 3 this spring; yarded 249,000 feet the day before moving, 269,000 feet the day we moved, and 257,000 feet the day following the move. The move was about 4 miles. The men took dinner in the old camp and supper in the new without losing time in the yarding. As the camp carries its own 1,000-gallon water tank, it could give the men their usual accommodations on a switch or siding if necessary. This was a camp of 160 men. I have known of instances where such a move would keep most of the crew busy for several days or at least one day. A camp of this size costs about \$350 per day to operate, so a little time saved makes quite a showing.

(d) *Class of men attached to a camp of this sort.*—A good many men in the woods would rather work in a camp where the living and working conditions are right than in another camp where the wages may be a little higher but the living conditions poor. We do not give the camps all the credit for this by any means. A large part of it is due to the foreman and his ability to handle the better class of men. The fact remains that in Camp 3 during the time it has been operated [1914 and 1915], we have had more "top" men (who were foremen and booktenders in normal times) than in any other camp of which I have knowledge. And it shows up in the work. Operating in a scattering "show," we got from two to four cars more per day than we had counted on, which was due very largely to the class of men we had in our rigging crews.

(e) *Distance from work.*—As the camp can be moved more cheaply than a more permanently located camp, we can move oftener and keep the men nearer their work. There are often small, more or less isolated pieces of timber to be picked up now and then, and a camp on wheels is very handy in such instances.

(f) *Cost of clearing site.*—Requires a smaller camp ground, and less clearing. A space 60 feet wide by 400 feet long will serve for a three-side camp.

(g) *Cost.*—Such a camp costs from \$9,000 to \$12,000, depending on the material put into it. In terms of a one-side camp this amounts to from \$3,000 to \$4,000 a side, which is reasonable even when considering the cost of the old-time board shack camps. One-side camps on wheels have been built in our country at a cost of \$4,000 to \$7,000, everything except the bunk cars and possibly the blacksmith shop being the same for a small as for a large camp.

The camp referred to by Mr. Martin as Camp 3 consists of 12 cars set in 2 rows, 6 on each side, with a walk between. Movable steps connect this walk with the various compartments. The whole camp, inside and out, is well lighted with electricity. The cars are set close to the railroad track, so that they can be steamed out when the need arises, the steam being furnished by a locomotive.

The cars are mounted on trucks rated at 60,000 pounds capacity and having $3\frac{3}{4}$ -inch journals. The framework on which the floor joists rest consists of six 6 by 12 inch longitudinal sills surmounted by 10 by 14 inch body bolsters and 10 by 12 inch end sills. These are reinforced by six $1\frac{1}{4}$ -inch truss rods extending the length of the car. All cars but one are 14 feet wide and 60 feet long. The other car, the cook house, is 14 feet wide and 36 feet long. The cars are sided with 6-inch drop siding and painted yellow with white trimmings. The cook house, dining cars, and all cars used as living quarters are ceiled on the inside with beaded ceiling, painted and varnished.

Windows and doors are sliding. A cupola roof raised about 3 feet above the main roof gives room for ventilating transoms. The main roof is shingled, and the cupola roof is covered with corrugated roofing.

The kitchen is modern in every respect. Many hotels do not have the modern cooking equipment which is to be found in it. It has a triple range with hood, two double-deck, zinc-covered serving tables on casters, built-in drawers and bins, a raising closet, hot-water tank, etc. Coal is used for fuel.

Two of the cars are used for diners, one at each end of the kitchen car. This arrangement simplifies the handling of food. These cars have a seating capacity of 175, with sleeping accommodations for the cookhouse crew in the end of one. Heavy crockery dishes are used because they are easy to clean and have no enameled surface to chip off into the food.

A car stationed immediately opposite the cookhouse and connected by means of a bridge is used for a warehouse and meat shop. This arrangement places the supplies needed in the kitchen close at hand. On the top of this car is a water tank, which supplies water by a gravity system to all parts of the camp. The meat room is in one end of the storeroom and just under the water tank. It is zinc lined and has sawdust-filled walls.

Five of the cars are used for sleeping quarters, each being divided into three compartments, accommodating 10 men each, or 30 men to a car. Each compartment is equipped with five double iron bunks with springs and mattresses, a sink with hot and cold water, shelves and hooks for clothes, steam heat, electric lights, and individual soap dishes. This division of the sleeping cars makes it possible for the men to form congenial groups.

One of the cars is used for a bath, dressing, and drying room. The bath room is equipped with six shower baths and a dressing room. The operator furnishes the soap. At the other end of the car is a drying room for the men's clothes. Batteries of steam coils laid on the floor under racks furnish sufficient steam to dry garments thoroughly in one and a half hours.

A reading and writing room $14\frac{1}{2}$ by 22 feet is situated at one end of the warehouse, where daily papers, magazines, and writing material are kept.

Another car, besides furnishing sleeping rooms for the office force, is used as a general camp office and commissary. A portion of this car is used for the company's civil engineer. The engineer's room, which has skylights, is fitted with a drafting table, map racks, an instrument closet, and a double bunk for the engineer and his assistant.

The blacksmith and machine shop is installed in another car. The electric light, power, and heating plants are also located in the same car. Steam heat is furnished by a 35-horsepower internal-fire-return tubular boiler. Electric light is generated with a $4\frac{1}{2}$ -kilowatt, 200-light dynamo. Oil, stored in a 1,000-gallon tank, is used for fuel.

The toilet is as well built as the rest of the camp, also as well lighted. It has screened ventilators and covered seats so arranged that they close automatically when not in use.

The hog pens are situated at the headquarters camp, all the swill being hauled from the camp in sanitary covered cans.

(2) *Portable camp on skids*.—The buildings of a portable camp on skids are moved from one location to another on logging cars or by means of donkey engines. They must be of a size that can be loaded readily on the cars. Strength in construction is an important factor, because of the frequent handling to which they are subjected. This type of camp has proved more satisfactory than the ordinary permanent camp. With the exception of the initial cost, it has no advantage over the camp on wheels, and it has some fundamental disadvantages.

In the case of one company, the living quarters are 10 by 14 by $7\frac{1}{2}$ feet, with a 3-foot gable. These cabins are substantially constructed, are sided with dressed and matched lumber, and have a rubberoid roof. There is a door in front and two sliding windows at the rear. For convenience in moving, the cabins are set on runners. The interior of each is furnished with three single iron bunks, a stove, and like accommodations. The approximate cost of each cabin was \$50. Iron bunks, mattresses, a stove, etc., raise this figure to \$75. At this rate, the living quarters for 99 men cost \$2,475. The efficient life of these cabins ranges from 7 to 10 years. Twenty-three cabins, all logging tools, equipment, etc., were loaded and hauled a distance of $3\frac{1}{2}$ miles in 18 hours. In another case similar cabins 14 by 30 feet and accommodating eight men were constructed for \$100. To furnish one of these cabins with double iron bunks, mattresses, a stove, etc., cost about \$50. At this rate accommodations for 96 men cost \$1,800.

The cost of the dining room and kitchen varies, depending on the type and size of building, also on whether it is of permanent or take-down construction. One stationary dining room and kitchen, large enough for 90 men, cost \$900; another, large enough for 200 men, cost \$1,500. These figures include tables of all kinds, bins, etc. The dining room and kitchen equipment—range, cooking utensils, dishes, etc.—cost \$600.

(3) *Stationary camps*.—Some of the most ably managed companies prefer large camps, not constructed to be moved, in which

from 150 to 300 men are accommodated, the men being taken to and from their work by train when working at a distance. The labor policy of the operator usually has something to do with the type of camp adopted. Where the policy is to encourage married men who want their families near them large and more permanent camps are used. Superintendents who do not permit families in or near the camps most often favor portable camps.

In one operation the permanent camp for single men consists of two large two-story buildings of modern design. One of the buildings is used for a bunk house for 100 men. This is plastered and painted and kept clean and sanitary. It is well ventilated, electric lighted, and has hot and cold water and a modern sewerage system. In each of the rooms there are four single iron beds, four lockers, four chairs, a table, and a droplight. The washroom at the rear of the building has a concrete floor. It is large enough to accommodate 10 men at one time.

The cookhouse, which is on the first floor of the other building, consists of a well-equipped kitchen and a large well-lighted dining room with a seating capacity of 125. Above the cookhouse is the recreation hall, fitted with two pool tables, card tables, reading and writing tables, a barber shop, and a bathroom.

The camp has graded streets, lined with neat cottages. There is a church, school, meat market, and some other shops besides the company store.

This is the ideal type of camp, supplying, as it does, pleasing and sanitary living quarters and surroundings for both single and married men. Unfortunately there are few camps of this type in the region.

Of course it would be impossible to have such a camp in connection with all logging operations. In the camp referred to the company has a 15-year supply of timber within a 15-minute ride on the logging road from the camp. The camp runs steadily, only shutting down for a few days at the Fourth of July and a week or so at Christmas.

WORKMEN'S COMPENSATION ACTS.

Until recently the responsibility of compensating injured laborers was regulated by employers' liability laws. These held the employer liable for accidents when he did not conform to the law. The employers protected their interests through liability insurance companies. This arrangement proved unsatisfactory. Lawsuits were common and proved a cumbersome method for determining whether compensation was due an injured workman or his dependents. Liability insurance was seemingly too expensive. On the other hand, injured workmen expended large sums of money for attorney's fees.

In addition compensation through liability laws tended to create an antagonistic feeling between employer and employee.

About one-half the States have passed workmen's compensation acts which provide for the payment by the State of specified sums to workmen for injuries received in the course of their employment, without the necessity of expense or delay. Both Washington and Oregon have workmen's compensation acts. In Washington the provisions of the act are obligatory on both the employer and the employee, the employers being required to pay monthly to the State a percentage of their pay rolls, the rate varying according to the hazard of the various occupations. In Oregon the act is of the presumptive elective type. While employers have the right to elect not to become subject to the act, they automatically come under its provisions if they do not serve written notice of rejection on the State. Employees in Oregon are also required to pay 1 cent for each day or part of day employed, the employers being authorized to make the collections.

In Washington the maximum rates have proved higher than was necessary, making it unnecessary for the operators to contribute toward the fund each month. The basic and assessed rates for the different departments of the logging operation for 1912, 1913, and 1914 were as follows:

TABLE 3.—*Rates of the Washington workmen's compensation act.*

Class of work.	Basic rate.	Assessed rate.						Average net equivalent rate for 1912, 1913, and 1914.
		1912		1913		1914		
		Months called.	Net equivalent rate.	Months called.	Net equivalent rate.	Months called.	Net equivalent rate.	
	<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>		<i>Per cent.</i>	<i>Per cent.</i>
Railroad construction.....	5	6	2.5	4	1.67	10	4.16	2.78
Railroad operation.....	5	6	2.5	4	1.67	10	4.16	2.78
Railroad maintenance.....	5	6	2.5	4	1.67	10	4.16	2.78
Logging proper.....	2.5	8	1.67	11	2.29	8	1.667	1.875

In Oregon the basic rates for the classes of work performed in logging are:

	<i>Per cent.</i>
Railroad construction	5
Railroad operation.....	5
Railroad maintenance.....	5
Logging proper.....	3½

The Oregon act makes provision for the assessment of lower rates. Where the accidents in the case of a given employer during the first year he is operating under the act do not require the State to pay out an amount in excess of 50 per cent of the employer's payments during that period, the employer's rate during the second year is

reduced by 10 per cent. With a like experience during the second year the rate for the following year is reduced by a similar amount. This act resembles that of Washington in that employees are exempt from assessments whenever the surplus in the fund has assumed certain proportions. The act has been in force for such a short period that it is not possible to state what it will cost the employers on the average.

TAXATION.

The general property tax system is in vogue in Oregon and Washington, and, with few exceptions, all property, both real and personal, is taxed for State and local purposes. The levy varies considerably by districts in a given year, and in a given district from year to year, ranging from 20 to 30 mills in the suburban districts where logging operations are located.

The tax on logging operations, exclusive of their standing timber, amounts to from 3 to 5 cents per thousand feet of output.

SCALING AND GRADING.

In Oregon and Washington the Scribner and Spaulding log rules are in general use, the former being the preferred rule in Washington, the latter being almost universally used in Oregon. The Scribner rule is used by the Puget Sound Log Scaling and Grading Bureau, the Spaulding rule is the standard rule of the Columbia River Log Scaling and Grading Bureau. The Forest Service in national forest timber sales uses the Scribner Decimal C rule, which is a slight modification of the old Scribner rule.

In Oregon and Washington logs are always measured at the small end inside the bark, unless some other arrangement is agreed to by both parties to the sale. Logs are usually cut from 2 to 9 inches longer than standard lengths of boards, to allow for waste in handling and manufacture. This additional length is disregarded in scaling.

Log rules give the number of board feet in logs which are straight and sound. If logs are unsound, or otherwise defective, a certain allowance must be made by the scaler and the determination of the amount in board feet requires great skill.

FOREST SERVICE SCALING.

In a general way, Forest Service scaling practice is the same as that of the log scaling and grading bureaus and independent scalers of the region. It differs, however, in some particulars, which should be thoroughly understood by applicants for national forest timber; for the scale resulting from Forest Service practice, as a rule, is larger than that resulting from commercial scaling.

Briefly, scaling, as practiced by the Forest Service, is the measurement of sound material in the log and relates to quantity rather than quality. National forest timber, therefore, is scaled in accordance with the defect in the log and not in relation to any particular grade of lumber it will produce. On the national forests in Alaska and west of the summit of the Cascade Mountains in Oregon and Washington, logs up to and including 32 feet in length are scaled as one log; lengths from 34 to 64, inclusive, are scaled as two logs as nearly equal in length as possible in even feet, and increasing the diameter of the second log according to the taper of the first. Greater lengths than 64 feet are scaled as three logs, making the division as nearly equal as possible in even feet.

Timber sale contracts specify a definite overlength for trimming. This allowance is adapted to different logging conditions and to large and small timber. Three inches overlength may prove sufficient in small timber where danger from brooming is slight, while 9 inches or more may be reasonable in sales of large timber or where the danger of brooming in driving or chuting is great.

All diameters are measured inside the bark at the top end of the log, being rounded off to the nearest inch above or below the actual diameter. Logs which have a diameter exactly halfway between inches are thrown to the next lower inch. If logs are not round, they are scaled on the average diameter. Several diameters may be measured where necessary to obtain a fair average.

The Forest Service has formulated a number of rules for making discounts for defects, realizing that the effect of rot and other defects upon logs of different species and in different regions varies so greatly that no rule for making deductions can be applied inflexibly, and that the constant exercise of good judgment by scalers, based upon an accurate knowledge of local timber secured by seeing defective logs opened up under the saw, is essential.

Every timber-sale contract defines exactly the material to be classed as merchantable under its terms.

The methods of manufacture of particular purchasers are not taken into account by scalers. No attempt is made to adjust the scale to losses due to poor equipment or inefficient methods, to match up gains from exceptionally close utilization, or so modify the scale as to eliminate losses resulting from selling the log product on a different scale. The function of a Forest Service scaler is to determine the amount of sound material in the log as uniformly as possible, whatever the mill tally or the selling scale may be. The Forest Service gives no assurance or promises on the amount of the overrun. Systematic checks on the local scale are made by more experienced scalers of special competence. In case of a serious complaint

the Service makes special check scales by the best men in its organization.

LOG SCALE THE BASIS IN LOGGING COST CALCULATIONS.

Loggers and lumber manufacturers uniformly think of logging costs in connection with the 1,000-foot unit. Loggers invariably prorate the logging costs on the basis of the log scale. Lumber manufacturers do not adhere to a uniform practice, sometimes prorating the logging costs on the mill tally, sometimes on both the mill tally and log scale. These two standards seldom agree, and it is necessary in a given case to know what standard has been used if one would avoid confusion. The product of the mill ordinarily overruns the log scale from 4 to 30 per cent, depending on the size, taper, and soundness of the timber, the thickness of the saws and other matters of mill equipment, the exact dimensions to which lumber is sawed, the class of material manufactured, and the loss in finishing and seasoning.

In this bulletin logging costs are uniformly based on the 1,000-foot log-scale unit unless an exception is noted. Logging-cost statements are based on the selling scale and not on a camp or Forest Service scale.

COST.

The bulk of the logs sold in the log markets of the Columbia River and Puget Sound regions are scaled by two log scaling and grading bureaus, corporations owned by independent loggers. In the Grays Harbor and Willapa Harbor regions scaling is done by independent scalers and costs about 5 cents per thousand feet.

Most logging operators who keep detailed cost accounts find it necessary to employ a camp scaler. A camp scaler is necessary in connection with practically all forms of bonus systems. Some camps get along without a camp scaler, keeping track of the output of the camp or the several units of production through a log or car count. A camp scale is not ordinarily considered as accurate as a selling scale. The camp scalers are paid from \$75 to \$125 per month.

Scaling in national forest timber sales is done by men regularly employed and paid by the Forest Service, which makes it possible for purchasers of national forest timber to get along without camp scalers. Purchasers who sell in the log markets, however, have to pay for a selling scale, as the Forest Service scale is not accepted by lumber manufacturers.

GRADING RULES.

As a general thing logs are sold by grades and species, so that it is desirable in most cases to sort the logs in rafting, each raft being

made up of logs of one grade or species. The grading rules used by the Columbia River Log Scaling and Grading Bureau are as follows:

No. 1 logs.

No. 1 logs shall be 30 inches or over in diameter inside the bark at the small end, reasonably straight grained, and not less than 16 feet long, and shall be logs which, in the judgment of the scaler, will contain at least 50 per cent of their scaled contents in lumber in the grades of No. 1 and 2 clear.

In a general way a pitch ring is not a serious grade defect in a No. 1 log, provided its location and size do not prevent the logs cutting the required amount of clears. The same applies to rot.

Pitch pockets, seams, knots, etc., are defects which impair the grades in proportion to their effect on the amount of clears the log contains. A No. 1 log will admit of a few small knots, but must be surface clear for at least four-fifths of its length; a few pitch pockets, as permitted in the grade of clear lumber, but no combination of defects which will prevent the required percentage of clears.

No. 2 logs.

No. 2 logs shall be 16 inches or over in diameter inside the bark at the small end, not less than 16 feet long, and having defects which prevent its grading No. 1, but which will, in the judgment of the scaler, be suitable for the manufacture of lumber principally in grades of merchantable and better.

No. 3 logs.

No. 3 logs shall be 12 inches or over in diameter inside the bark at the small end, not less than 16 feet long, having defects which prevent its grading No. 2, and, in the judgment of the scaler, be suitable for the manufacture of the inferior grades of lumber.

Cull logs.

Cull logs shall be any logs which do not contain 50 per cent of sound lumber. All logs to be scaled by the Spaulding Rule.

The grading rules used by the Puget Sound Log Scaling and Grading Bureau are as follows:

No. 1 logs.

No. 1 logs shall be logs in the lengths of 16 to 32 feet and 30 inches inside the bark at the small end, and logs 34 to 40 feet and 28 inches in diameter at the small end, and shall be logs that, in the judgment of the scaler, contain at least 50 per cent of their scaled contents in lumber in the grades of No. 2 clear and better.

No. 2 logs.

No. 2 logs shall not be less than 16 feet long and having defects which prevent their grading No. 1, but which, in the judgment of the scaler, will be suitable for the manufacture of lumber principally in the grades of merchantable and better.

No. 3 logs.

No. 3 logs shall not be less than 16 feet long and having defects which prevent their grading No. 2, but which, in the judgment of the scaler, will be suitable for the manufacture of common lumber.

Cull logs.

Cull logs shall be any logs which, in the judgment of the scaler, will not cut 33 $\frac{1}{3}$ per cent of sound lumber.

Rules for the grading of cedar, Douglas fir, spruce, and hemlock logs or shingle bolts were put in force in British Columbia not very long ago by the Forest Branch. The rules follow:

GRADING RULES FOR CEDAR LOGS.

No. 1 logs.

Logs 12 feet and over in length, 20 inches and over in diameter, that will cut out 50 per cent or over of their scaled contents in clear lumber. In cases of split timber above diameters will not be considered.

No. 2 logs.

Logs 12 feet and over in length, 14 inches and over in diameter, that will cut out merchantable or better, but which will not cut out to grade No. 1. This grade will also admit of a good grade of shingle log.

No. 3 logs.

Rough logs that are only fit for a low grade of shingles, shiplap, or dimension timbers.

Culls.

Logs lower in grade than No. 3 will be classed culls.

GRADING RULES FOR DOUGLAS FIR.

Flooring logs.

Logs suitable for flooring, reasonably straight, not less than 20 feet long, not less than 30 inches in diameter, clear, free from such defects as would impair their value for clear lumber.

Merchantable logs.

Logs not less than 14 inches in diameter, sound, reasonably straight, free from rotten knots; the grain straight enough to insure strength.

Rough logs.

Logs having visible defects such as crooks, bad knots, or defects that would impair the value and lower the grade of lumber below merchantable.

Cull logs.

Logs which will not produce 50 per cent of their contents in salable lumber shall be classed as culls.

GRADING RULES FOR SPRUCE, PINE, AND HEMLOCK.

No. 1 logs.

Logs 12 feet or over in length, 30 inches in diameter and over, up to 32 feet long; 28 inches if over 32 feet long; reasonably straight, clear, free from such defects as would impair their value for clear lumber.

No. 2 logs.

Logs not less than 14 inches in diameter, sound, reasonably straight, free from rotten knots or bunch knots; the grain straight enough to insure strength.

No. 3 logs.

Logs having visible defects such as crooks, bad knots, or other defects that would lower the grade below merchantable or No. 2.

Culls.

Logs which will not cut 50 per cent of their contents in salable lumber shall be classed as culls.

GRADING RULES FOR SHINGLE BOLTS.

Bolts to be measured in the following manner: To be as closely piled as possible, 4 feet high, 8 feet long, and the average number of pieces taken in the piles; the quantity to be obtained by dividing the number of pieces by the average contained in the piles. If piled loosely, sufficient allowance to be made to make up a cord of closely piled bolts.

No. 1 bolts.

(a) To be of first-class timber of an average of not more than 30 bolts to the cord, 52 to 54 inches in length, straight, well made, hearted, and barked.

(b) Seventy per cent of the bolts to be clear; balance to allow of two small knots in each bolt, 1 inch in diameter.

(c) To be free from rot, shakes, and knot holes and other defects.

No. 2 bolts.

(a) To be well made, hearted, and barked, and of an average of not more than 36 bolts to the cord, 52 to 54 inches in length.

(b) To be free from rot, shakes, and worm holes.

No. 3 bolts.

(a) To be hearted and barked, not more than 40 bolts to the cord, 52 to 54 inches in length.

(b) Twenty-five per cent to be clear; balance to allow any bolt which has two cuts, with one knot 2 inches in diameter in each cut.

(c) To be free from rot, shakes, and worm holes; any bolts not up to standard of the grades to be considered culls.

PLANS.

The planning of the operation has received more attention in the Douglas fir region than elsewhere, largely because of the character of the country and the logging methods. Some operators, however, still cling to old methods.

All operations in the region are cruised, and usually some form of report is made and a map of some character submitted. The reports are usually conservative, and in many cases the maps are little more than sketches showing the more striking features of the area. Many operators have found it desirable to check their cruises and prepare topographic maps, on which are shown the following: The holdings of the company; the distribution of the stand by species, quality, and quantity; the location of streams, ridges, roads, trails, and tentative camp sites; the location of main logging railroads; and the division of the area into logging units. As to the question of accuracy, operators are governed by the character of their country and the uses to which the map is to be put. Where the map is to be used for the location of railroads and the estimation of logging costs, the field work is done intensively. The practice is still followed, however, by some operators of allowing certain woods employees to carry very valuable information regarding the timberlands in their heads, instead of having it on paper in the office.

RECORDS.

Operators as a class have not regarded the preparation of records as of much value, except in the case of operating costs. There are few operators who keep carefully written records of the achievements of past years and study them to weed out weak points in their management and methods. The most that is done is to ponder over the general experience of the past and, in a rather unsystematic manner, attempt to increase the efficiency of the work. This is remarkable in view of the fact that the managers in many cases are stockholders, and that cost figures, in connection with written records, provide the only sound basis on which new methods and principles may be founded. It should be understood that all operators do not neglect this means of improving their methods. Some are following modern business methods in this respect and to their advantage.

ACCOUNTS.

At present (1916) there are differences in the accounting methods of loggers because of the peculiarities of individual operations and because of a lack of understanding of the principles underlying proper accounting. Differences in logging methods, in the items which enter into the cost-keeping statements, in the methods of handling depreciation and the like, make it impossible for operators, even in the same

region, to discuss intelligently their costs of production, especially the details. As a result, a feeling has arisen within and without the industry that a profitable field of endeavor would be the investigation of the basic principles which underlie costs and cost keeping and the preparation of a uniform cost sheet. Few question that a standardized cost-keeping system is practicable and would be of lasting value to the logging industry.

DEPRECIATION.

Until recently many operators followed the unwise and dangerous practice of taking no account of depreciation. The method of handling this account is optional with the operators, no provision for depreciation being prescribed by law; but the passage of the Federal income tax law has made it desirable for all operators to write off on their books a certain amount.

Depreciation is the shrinkage in value of an asset that results from its use. Lessening of the value of assets may be due to ordinary wear and tear, to physical deterioration, to inadequacy for the current needs of an operation, or to the exhaustion of available timber. The amount of such deterioration is charged against the operating profits, and so can be considered as an amount paid out of the proceeds of the business. The best concrete illustration is a sinking fund withdrawn from the proceeds of the business at regular intervals, deposited in a special account, and used to pay off bonds as they become due. In National Forest stumpage appraisals depreciation is reckoned as if charged off and withdrawn from the business at the end of the year. It is a sum, prorated over every thousand feet of timber cut, which in the course of the operation pays back the reduction in value of the fixed investments.

The rate of depreciation varies widely with the nature of the investment. Improvements are stationary, and so can be used only where they are built. They include all buildings, wagon and pole roads, railroad grades, bridges, splash dams, etc. The rate of depreciation on each improvement depends primarily upon the amount of timber which it can properly be used to log. When all of the tributary timber is removed, the improvements have no residual value. Improvements located with reference to large supplies of timber, like logging railroads, may have a very long life. Their rate of depreciation is correspondingly low. Equipment can be moved from place to place; so its depreciation depends primarily upon wear and tear, or the length of the ordinary working life. It includes tools, steam logging machinery, cables, railroad steel, rolling stock, etc. The working life given to different equipment in this publication is intended to represent current industrial experience in the region.

In times past some logging operators wrote off an arbitrary amount for depreciation. This was done to equalize profits, a large amount being charged off at the end of a prosperous year. Most operators charge off annually a certain percentage of the original cost, the amount being determined from an estimate of the life of the equipment. For example, a logging engine with an estimated life of eight years and no value at the end of that time is reckoned as depreciating $12\frac{1}{2}$ per cent of its first cost each year. This method is used in making national forest timber appraisals.

AVERAGE TOTAL LOGGING COSTS.

The cost of logging in the region varies greatly; in 1913 it ranged from \$4 to \$7.50 per thousand feet. An average logging cost figure for a large region is rather indeterminate. In a given case the cost of logging may be lowest the first year or as soon as the business hits its stride, and increase gradually from year to year, the books showing the highest cost the last year, when the operator is cleaning up. This is due for the most part to the way the area is opened up, the operator pursuing the logical method of logging first the more accessible areas, which, as a rule, constitute the best logging chances. Methods of accounting can be devised which will tend to equalize the annual profits; but they can not change the fixed conditions which cause the actual cost of logging to be lower during the early life of the operation. The conclusion to be drawn is that an operator does not know what his average logging cost is until the last log has been hauled. Such being the case in a given operation, any statement purporting to represent the average logging cost for a region, even though it is based on sufficient accurate data and correct mathematical principles, is nothing more than a close approximation.

Table 4 gives the average cost per thousand feet log scale for delivering logs from the tree to the cargo mills of Puget Sound, the Columbia River, Grays Harbor, and Willapa Harbor in 1913. The average cost for the Puget Sound region is based on the output of 20 large camps, or about 900,000,000 feet, this output representing 75 per cent of the total output of the camps that dump into the Sound. The average cost for the Columbia River region is based on an output of 10 large camps, or about 385,000,000 feet. In the case of Gray's Harbor and Willapa Harbor regions the average cost is based on a smaller output, which makes the chance for error greater.

While it is reasonable to suppose that the average cost of logging in these four regions is approximately the same, too much stress should not be laid on the fact that this statement shows such to be the case. These costs are based on the selling log scale, and lack of

standardization in scaling methods would indicate that this unit of measure varies somewhat by regions. Furthermore, the outputs on which these figures are based, with the exception of the Puget Sound region, are not large enough to give nicely accurate results. This is particularly true of the Grays Harbor and Willapa Harbor regions.

The statement does not include the cost of stumpage, interest of any kind, discounts on logs sold, or taxes on the standing timber. It includes only the cost of transforming and sorting the logs and taking them to the point at which they are manufactured into lumber. The manufacturers, as a rule, pay the cost of towing in the Puget Sound and Columbia River regions; in the Grays Harbor and Willapa Harbor regions the logger usually pays it.

The classification of costs given in the statement is not ideal. It is in fact an expedient. Operators use different classifications. In collecting the data the classifications of operators were followed, and later the classified costs were distributed in the best possible manner.

TABLE 4.—Average cost per thousand feet in 1913 for delivering logs from the tree to the cargo mills of the Puget Sound, Columbia River, Grays Harbor, and Willapa Bay regions.

Item.	Region.			
	Puget Sound.	Columbia River.	Grays Harbor.	Willapa Harbor.
1. Felling and bucking (labor).....	\$0.683	\$0.70	\$0.62	\$0.62
2. Woods to car (labor).....	1.259	1.31	1.81	1.81
3. Railroad (spur) and pole road construction (labor).....	.586	.46	.50	.64
4. Train crews (labor).....	.206	.24	.14	.09
5. Dumping and rafting (includes contract work) (labor).....	.211	.16	.24	.20
6. Supplies and maintenance (labor and material) of railroad, dump, and boom.....	.177	.25	.14	.06
7. Supplies and maintenance (labor and material) of equipment, tools, buildings, etc.....	.307	.45	.32	.32
8. Fuel for locomotives, logging engines, shops, etc.....	.239	.23	.16	.14
9. Wire rope.....	.137	.15	.19	.20
10. Depreciation, equipment.....	.24	.28	.30	.30
11. Depreciation, main line railroad grade, boom, and buildings.....	.066	.17	.07	.06
12. Scaling.....	.049	.05	.05	.05
13. Return of boom sticks.....	.046	.07		
14. Log freight.....	.882	.43	.59	.75
15. Salaries and commissions.....	.139	.14	.15	.15
16. Taxes.....	.029	.05	.035	.035
17. Industrial insurance.....	.096	.11	.08	.08
18. Sundry expenses.....	.076	.05	.10	.10
19. Driving.....			.14	.10
20. Towing.....	5.428 .35	5.30 .50	5.635 .12	5.705 .080
Total.....	5.778	5.80	5.755	5.785

Item 2 includes the labor cost of yarding, swinging, roading, landing construction, and loading. The average cost of this work in any one of the four regions is higher than its average cost in camps that yard the logs direct to the track. The higher cost in the Grays Harbor and Willapa Harbor regions is due to the fact that a larger percentage of the timber is roaded relatively long distances to the railroads and drivable streams.

Item 3 includes the labor cost of spur railroad and pole road construction. Practically no pole roads are used in the Puget Sound and Columbia River regions, while in the Grays Harbor and Willapa Harbor regions they are necessary in many cases. The figures indicate that the cost per thousand feet for pole road construction may run as high as for railroad construction.

Item 4 includes the labor cost of train crews. Common carrier railroads are used more in the Puget Sound region than in the Columbia River region, which explains the lower cost in the former case. The loggers in the Grays Harbor and Willapa Harbor regions do not use the railroad so extensively as the loggers in the Puget Sound and Columbia River regions, the two former relying more on roading and river driving, which explains the lower cost.

Item 5 is an average of the labor cost at those camps which do this work by day labor, also those that do it by contract; the contract rates in some cases only include labor, in others the total cost of the work. The cost in the Puget Sound, Grays Harbor, and Willapa Harbor regions includes more contract work than in the Columbia River region, which explains the lower cost in the latter case.

Item 6 includes the cost of supplies and maintenance (labor and material) of the railroad, dump, and boom. The cost is highest in the Columbia River region. This is because railroads owned by operators are longer in this region than in the other three. Also less contract dumping, sorting, and rafting is done there. The next higher cost is found in the Puget Sound region. This is largely because the loggers operate railroads much more extensively in this region than in the Grays Harbor and Willapa Harbor regions.

Items 7, 8, 9, and 14. Reasons for seeming discrepancies are brought out in the notes on items 2, 3, 4, 5, and 6.

Item 15 includes the salaries of superintendents or managers, bookkeepers, etc., at the main office, which is detached from the woods; also fixed sums paid to individuals or companies for selling the logs. The cost of camp foremen, bookkeepers, timekeepers, scalers, etc., is prorated against the major steps in the logging operation proper.

The camps of the Puget Sound and Columbia River regions group by total logging costs as follows:

PUGET SOUND REGION.

Cost per thousand feet. ¹	Number of camps.	Total yearly output of camps included in statement.
		<i>Feet.</i>
\$4.00 to \$4.50.....	4	177,000,000
\$4.51 to \$5.00.....	2	100,000,000
\$5.01 to \$5.50.....	5	220,000,000
\$5.51 to \$6.00.....	3	180,000,000
\$6.01 to \$7.00.....	3	135,000,000
\$7.01 to \$7.50.....	3	84,000,000
Total.....	20	896,000,000

¹ Does not include towing.

COLUMBIA RIVER REGION.

		<i>Feet.</i>
\$4.00 to \$4.50.....	2	90,000,000
\$4.51 to \$5.00.....	2	80,000,000
\$5.01 to \$5.50.....	3	80,000,000
\$5.51 to \$6.00.....	1	55,000,000
\$6.01 to \$7.00.....	2	80,000,000
Total.....	10	385,000,000

The average cost of logging in connection with 19 inland mills in Oregon and Washington, as worked out by Mr. Austin Cary¹ on the basis of the lumber produced and sold, amounted to \$4.42 per thousand feet. The yearly output of the operations included in this statement ranged from seven to thirty-seven million feet. The difference between this average cost and the costs given in Table 4 can largely be explained on the ground that they are based on different units of measure; also by the fact that the average railroad haul is not so long in the case of the inland mills as of the cargo mills.

¹ Logging engineer, Forest Service.

FIXED INVESTMENT.

The capital required for equipment and improvements varies greatly, depending for the most part on the output of the camp and the length of the railroad haul. In the case of going concerns, it depends on the age of the operation or the amount that has been written off for depreciation. For example, in the case of the 20 Puget Sound camps which have been referred to—camps of varying ages—the fixed investment at each camp ranged from \$50,000 to \$750,000; in the 10 Columbia River camps, from \$75,000 to \$750,000.

The following tabulation shows the approximate amounts invested for equipment and improvements in the 20 Puget Sound camps, together with their approximate daily output:

Fixed investment for camps.	Number of camps.	Approximate daily output (1913).
		<i>Thousand feet.</i>
\$50,000 to \$100,000.....	4	80 to 200
\$100,001 to \$150,000.....	8	150 to 350
\$150,001 to \$200,000.....	3	200 to 250
\$200,001 to \$300,000.....	2	200 to 250
\$300,001 to \$400,000.....	1	500
\$400,000 to \$500,000.....	1	150
\$700,001 to \$800,000.....	1	300

LOG PRICES.

From the log prices, shown in Table 5, which gives the prevailing prices paid for different grades of Douglas fir logs (the bulk of the output) for each month from January, 1909, to September, 1916, it is apparent that the prices fluctuate considerably, but that the spread between No. 1, No. 2, and No. 3 grades is practically uniform. The normal prices are \$6, \$9, and \$12, and only when lumber prices are good do the log prices advance to \$7, \$10, and \$13. The prices shown in the table are based on log scale and are considerably higher than the net cost per thousand feet of lumber produced, because of the surplus or overrun of the lumber tally over the log scale. In accordance with the usual practice of the region, the buyer may, at his option, take a 2 per cent discount by paying cash.

The prices of cedar, spruce, and hemlock logs are less susceptible of discussion; because, for the most part, they are not based to any extent on standard grades. The following log prices, taken from a trade journal, of March, 1917, will illustrate this and will give a general idea of log values:

The stock of logs in the Columbia River district is not very heavy at this time, but ample for all demands. Present prices are: Yellow fir (large, old-growth Douglas fir), \$6, \$9, \$12, with some sales at \$5, \$8, \$11; camp-run, red fir (relatively small Douglas fir), \$8.50; hemlock, \$7; spruce, \$12; cedar, \$11.

There is a normal supply of logs on Puget Sound. Prices for fir on grade, are \$7, \$10, and \$13, respectively, with hemlock in demand at \$7. Cedar is in good demand and is bringing from \$10.50 to \$12, according to quality. No spruce is being offered.

There is no surplus of logs on Grays Harbor. Prices on fir* are \$6, \$9, and \$12; hemlock, \$6 to \$7; spruce, \$7 to \$20.

Log prices in British Columbia are firm, with the supply very light. Fir is selling at \$7, \$10, and \$13; hemlock, \$7.50; cedar, \$11.50 to \$13; and spruce around \$12.

TABLE 5.—Prices of Douglas fir logs per thousand feet, by regions, 1909–1916.

No. 1 LOGS.

Year.	Region.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909	Puget Sound.....	\$13.00	\$12.00	\$12.00	\$12.00	\$12.00	\$12.00	\$12.00	\$12.00	\$12.00	\$12.00	\$12.00	\$12.00
	Grays Harbor.....	12.50	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
	Columbia River.....	12.50	12.50	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00
1910	Puget Sound.....	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
	Grays Harbor.....	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
	Columbia River.....	12.00	12.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00	13.00
1911	Puget Sound.....	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00	11.00	11.00
	Grays Harbor.....	13.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00
	Columbia River.....	13.00	13.00	13.00	13.00	12.00	12.00	12.00	12.00	12.00	12.00	12.00	11.00
1912	Puget Sound.....	11.00	11.00	11.00	11.00	11.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00
	Grays Harbor.....	11.00	11.00	11.00	11.00	11.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00
	Columbia River.....	12.00	12.00	12.00	12.00	12.00	12.00	12.00	13.00	13.00	13.00	13.00	13.00
1913	Puget Sound.....	13.00	13.00	13.50	13.50	14.00	14.00	14.00	14.00	13.00	12.00	12.00	12.00
	Grays Harbor.....	13.00	13.00	13.50	13.50	14.00	14.00	14.00	14.00	13.00	11.00	11.00	11.00
	Columbia River.....	13.00	13.00	13.50	13.50	14.00	14.00	14.00	13.00	11.00	11.00	11.50	11.50
1914	Puget Sound.....	12.00	12.00	12.00	12.00	11.00	11.00	11.00	12.00	11.50	11.00	11.00	11.00
	Grays Harbor.....	12.00	12.00	12.00	12.00	11.10	12.00	12.00	12.00	11.00	11.00	11.50	11.00
	Columbia River.....	12.00	12.00	12.00	12.00	11.10	11.00	11.00	11.00	11.00	11.00	11.50	11.50
1915	Puget Sound.....	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	Grays Harbor.....	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.00
	Columbia River.....	11.50	11.00	11.50	11.50	11.00	11.00	11.00	11.00	11.00	11.00	11.00	11.50
1916	Puget Sound.....	12.00	12.00	13.00	13.00	13.00	13.00	13.00	12.00	.....	.....	.....	.....
	Grays Harbor.....	12.00	12.00	13.00	12.00	13.00	13.00	13.00	13.00	.....	.....	.....	.....
	Columbia River.....	13.00	13.00	12.00	13.00	13.00	12.00	12.00	12.00	.....	.....	.....	.....

No. 2 LOGS.

Year.	Region.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909	Puget Sound.....	\$9.00	\$9.00	\$9.00	\$9.00	\$8.50	\$8.00	\$8.00	\$9.00	\$9.00	\$9.00	\$9.00	\$9.00
	Grays Harbor.....	8.50	9.00	8.00	9.00	8.00	8.00	8.00	9.00	9.00	9.00	9.00	9.00
	Columbia River.....	8.50	8.50	8.00	9.00	8.00	8.00	8.00	9.00	9.00	9.00	9.00	9.00
1910	Puget Sound.....	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.50	10.00	10.00
	Grays Harbor.....	9.00	9.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
	Columbia River.....	9.00	9.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00
1911	Puget Sound.....	10.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00
	Grays Harbor.....	10.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	8.50
	Columbia River.....	10.00	10.00	10.00	10.00	9.00	9.00	9.00	9.00	9.00	9.00	9.00	8.50
1912	Puget Sound.....	8.00	8.00	8.00	8.00	8.00	9.00	9.00	10.00	10.00	10.00	10.00	10.00
	Grays Harbor.....	8.00	8.00	8.00	8.00	8.00	9.00	9.00	10.00	10.00	10.00	10.00	10.00
	Columbia River.....	9.00	9.00	9.00	9.00	9.00	9.00	9.00	10.00	10.00	10.00	10.00	10.00
1913	Puget Sound.....	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	9.00	9.00
	Grays Harbor.....	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	9.00	9.00
	Columbia River.....	10.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	8.00	8.00	8.50	8.50
1914	Puget Sound.....	9.00	9.00	9.00	9.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Grays Harbor.....	9.00	9.00	9.00	9.00	8.00	9.00	8.00	8.00	8.00	8.00	8.50	8.00
	Columbia River.....	9.00	9.00	9.00	9.00	8.00	8.00	8.00	8.00	8.00	8.00	8.50	8.50
1915	Puget Sound.....	8.00	8.00	8.00	8.50	8.50	8.50	8.00	8.00	8.00	8.00	8.00	8.00
	Grays Harbor.....	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.00
	Columbia River.....	8.50	8.00	8.50	8.50	8.00	8.00	8.00	8.00	8.00	8.00	8.00	8.50
1916	Puget Sound.....	9.00	10.00	10.00	10.00	10.00	10.00	10.00	9.00	.....	.....	.....	.....
	Grays Harbor.....	10.00	10.00	10.00	10.00	10.00	10.00	10.00	10.00	.....	.....	.....	.....
	Columbia River.....	10.00	10.00	9.00	10.00	10.00	9.00	9.00	9.00	.....	.....	.....	.....

TABLE 5.—*Prices of Douglas fir logs per thousand feet, by regions, 1909-1916—Continued.*

No. 3 LOGS.

Year.	Region.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1909	Puget Sound.....	\$6.00	\$6.00	\$6.00	\$6.00	\$5.50	\$5.50	\$5.50	\$5.50	\$6.00	\$6.00	\$6.00	\$6.00
	Grays Harbor.....	5.50	6.00	5.00	6.00	5.00	5.00	5.00	6.00	6.00	6.00	6.00	6.00
	Columbia River....	5.50	6.00	5.00	6.00	5.00	5.00	5.00	6.00	6.00	6.00	6.00	6.00
1910	Puget Sound.....	6.50	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
	Grays Harbor.....	6.00	6.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
	Columbia River....	6.00	6.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00
1911	Puget Sound.....	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.50
	Grays Harbor.....	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.50
	Columbia River....	7.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00	6.00	6.00	6.00	5.50
1912	Puget Sound.....	5.50	5.50	5.50	5.50	5.50	6.00	6.00	6.00	7.00	7.00	7.00	7.00
	Grays Harbor.....	5.50	5.50	5.50	5.50	5.50	6.00	6.00	6.00	7.00	7.00	7.00	7.00
	Columbia River....	6.00	6.00	6.00	6.00	6.00	6.00	6.00	7.00	7.00	7.00	7.00	7.00
1913	Puget Sound.....	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	6.00	6.00	6.00
	Grays Harbor.....	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	6.00	6.00	6.00	6.00
	Columbia River....	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	5.00	5.00	5.50	5.50
1914	Puget Sound.....	6.00	6.00	6.00	6.00	5.50	5.50	5.00	5.00	6.00	5.00	5.50	5.50
	Grays Harbor.....	6.00	6.00	6.00	6.00	5.50	6.00	5.00	5.00	5.00	5.00	5.50	5.00
	Columbia River....	6.00	6.00	6.00	6.00	5.50	5.00	5.00	5.00	5.00	5.00	5.50	5.50
1915	Puget Sound.....	5.50	5.00	5.50	5.50	5.50	5.50	5.00	5.00	5.00	5.00	8.00	8.00
	Grays Harbor.....	5.00	5.00	5.50	6.00	5.00	5.00	5.00	5.00	5.00	6.00	8.00	8.00
	Columbia River....	5.50	5.00	5.50	5.50	5.00	5.00	5.00	5.00	5.00	5.00	8.00	5.50
1916	Puget Sound.....	6.00	7.00	7.00	7.00	7.00	7.00	7.00	6.00	-----	-----	-----	-----
	Grays Harbor.....	7.00	7.00	7.00	7.00	7.00	7.00	7.00	7.00	-----	-----	-----	-----
	Columbia River....	7.00	7.00	6.00	7.00	7.00	6.00	6.00	6.00	-----	-----	-----	-----

FELLING AND BUCKING.

ORGANIZATION OF CREWS.

Laying aside the question of direct supervision, undercutting, felling, and bucking are sometimes performed by three crews. An undercutter, or notcher, selects the trees to be felled, determines the direction they are to be thrown, and makes the undercut. Two fallers, sawing together as a second crew, then finish the second step in felling. The undercutter, or head buckler, next marks off the log lengths for the guidance of the buckers, who work singly with cross-cut saws and cut the bole into lengths. As a rule, however, only two crews are used, the undercutting being done by the fallers. This is considered the best method.

In most of the large and better managed camps, a head buckler, working under the camp foreman, directs the work of felling and bucking, and marks off the log lengths. Occasionally in large timber and badly broken ground, the head buckler has an assistant to help mark off the log lengths, the resultant timber economies justifying the additional labor cost. In a few camps having a resident superintendent, the head buckler works under the superintendent rather than under the camp foreman, and only directs the work of the felling and bucking department, the marking of the log lengths being done by the buckers. A head buckler of the first class seldom has authority to hire his assistants, while one of the second generally has authority

both to hire and to discharge. There are a number of rather large and efficiently managed camps in which the camp foreman has direct charge of the felling and bucking, the activity of the man, or the character of the logging operation as a whole, making it possible for him to keep a close check on the felling and bucking work, make assignments, specify the log lengths, and see that waste does not occur.

The head fallers and, generally, each buckers are held responsible to the head buckers or camp foreman for the quantity and quality of the work done. In a few cases, however, the buckers work in crews of three or four, and one of their number, besides doing the regular work of a buckers, acts as a strawboss, marks off the log lengths, and reports at stated periods the number of logs of different lengths cut. If the fallers and buckers are working under a bonus system, or if the management is keeping a close check on the amount of work done by each worker, a competent scaler is necessary.

METHODS.

THE DIRECTION OF FALL.

The first step in the felling of a tree is the selection of the direction in which it is to be thrown. This is governed by a number of factors, of which the following are the most important:

(1) The lean of the tree. By the use of wedges, a tree standing perpendicularly may be sawed to fall in any direction. A heavily leaning tree may be thrown by the same means in any one of three directions, namely, as it leans, or to either side. If the lean is not too great, the tree may be thrown in any one of four directions.



FIG. 1.—Falling wedge.

However, with present standard equipment, that is, with the falling wedge (fig. 1), it costs too much to fell trees with other than a slight lean in a direction opposite to the lean, except to prevent excessive breakage and to avoid doing damage to improvements, equipment, etc.

(2) The simplification of the first step in transportation. Timber cut for power yarding as a general thing should be thrown away from or toward the direction of haul, so that it can be moved with the least trouble, especially where the logs are cut into long lengths. Where short logs are cut, this is not essential.

(3) The protection of workers and timber. Trees which are felled up steep slopes are less likely to break because the distance of fall is less. As a rule, however, this method is not used, because it is costly and dangerous. On such ground the trees are thrown down or along the side of the hill. On slopes where the timber will lie

where felled, it is felled upgrade and, as in the case of level ground, into the green timber as far as practical. The aim at all times is to select a spot, or bed, where the bole of the tree will not be broken by the fall and will do no damage to other timber. It is occasionally necessary to make a bed for the large trees by swamping and leveling the ground, or by felling small, inferior species.

(4) The simplification of the work of cutting the trees into logs.

(5) The avoidance of lodging one tree in another.

THE UNDERCUT.

A wedge-shaped notch, or undercut, with a horizontal base in most cases, is cut in the trunk of the tree in the direction of fall, to guide the tree and to prevent the bole from splitting before it is completely severed from the stump. The depth of the undercut varies with the size and lean of the tree and the direction it is to be thrown, ranging from one-fifth to one-fourth of the diameter. It is deeper proportionately in small than in large timber. The undercut in trees that lean heavily in the felling direction is made deeper than usual in order to insure a clean break. For example, the undercut of a perpendicular tree 60 inches in diameter is about 15 inches deep; of a tree of the same size leaning 5 feet, about 24 inches deep; leaning 10 feet, about 30 inches deep. In trees that lean away from the felling direction and require heavy wedging, a smaller undercut is made in order to increase the power of the wedges. Under the latter condition the undercut may not be made until the felling cut is well in and the wedges started. The undercut is placed from 2 to 4 inches below the point at which the felling cut is to be started on the opposite side of the tree. The horizontal cut in most cases is made with a falling saw (fig. 2), the undercut being completed with a falling ax (fig. 3). In relatively small timber both faces of the undercut may be made with an ax. Not infrequently the height of the stumps cut makes the use of springboards (fig. 4), or some sort of scaffold, necessary when undercutting. Then, too, the fallers prefer to stand on springboards, even when the size of the roots does not make such a contrivance necessary. The ground around trees in the woods is more or less soft and does not give a firm foothold. If the ground is sloping, the tendency is for the

FIG. 2.—Falling saw.

feet of the fallers to slip downhill. The springboard, together with calked shoes, prevents this. Furthermore, there is a certain spring in the boards when the fallers are working that makes it easier for them to pull the saw.

THE FELLING CUT.

The undercut completed, the next step is the making of the felling cut. This is done with a falling saw. Prior to about 1880 the felling cut was made with an ax but not so satisfactory. Wedges can not be used when felling with an ax, so that it is difficult to throw a tree in any direction except that in which it leans. Furthermore, the output of a set of fallers is considerably less when working only with an ax than when working with saw and ax. Then, too, the loss of wood is larger when the ax is used exclusively.



FIG. 3.—Falling ax.

The felling cut is started slightly above and opposite the undercut. When the saw has buried itself in the wood, steel wedges and plates are driven in behind it to prevent binding. In small, second-growth timber, the fallers may saw in a direction parallel to the undercut. As a rule, however, they change the direction of the cut so as to be continually sawing across a corner. If a tree leans heavily in the direction it is to be thrown, a different method is used. Such

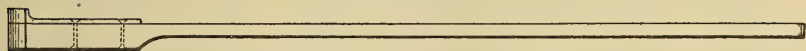


FIG. 4.—Spring or chopping board.

a tree will naturally break off while there is still considerable wood holding it to the stump; and, if any of this wood is on the outside of the tree, there is a likelihood of its splitting up the side of the butt log. To prevent this, the fallers make side cuts, so that there is nothing to break when the tree falls except the wood on the inside of the stump. Much the same method is used with a tree that is rotten about the heart.

When it is desired to draw a tree slightly to one side of the direction in which it leans, the greatest thickness of wood between the felling cut and undercut is left on the side toward which it is desired to draw the tree. Wedges are also employed with this latter method.

Here, as in the case of undercutting, springboards are generally used.

BUCKING.

In bucking, the men work singly with bucking saws (fig. 5), the size of the trees and the way they lie making this, as a rule, the cheapest and most practical method. This crew cuts no limbs from the trees other than those that hinder the work of bucking. The limbing is left to a man called a swamper, knotter, or limber, who works with the initial transportation or yarding crew. A swamping ax (fig. 6) is used for this purpose.

In this region, where the timber is large and the ground steep and badly broken, bucking is difficult and dangerous work, requiring a high degree of skill.

The buckers are usually confronted with one of four situations, depending on the position of the felled tree:

(1) When the bole is lying flat on the ground, the bucker's work is simple, for after removing the bark, earth, etc., from the line of cut, he can easily saw through from the upper side, or if need be, from the lower. Before the saw begins to bind, bucking wedges (fig. 7) are driven into the kerf.

(2) When the bole is supported at both ends, the cut is started on the upper side and continued for about one-third of the distance through the log, or as far as the bind will permit. A cut is then started on the under side and continued until the log is severed. The bole, as a rule, is supported by heavy props placed under one or both sides of the cut. If the tree is not hung badly, the cut may be made from the upper side by using side wedges; that is, ordinary wedges driven in with the grain across the cut to prevent the log from rolling, binding, slabbing, or splitting.

(3) When the tree is supported at one end, care must be exercised to avoid splitting slabs from the under side. This is avoided by sawing on the under side of the bole until the saw starts to bind. In addition, the log, as a rule, has its free end supported by a heavy prop. The cut is continued, on the upper side, until the log breaks off from its own weight.

(4) When the bole is sprung between stumps, or side bound, it will spring back when sawed; and the general practice is to chop a deep kerf on the concave

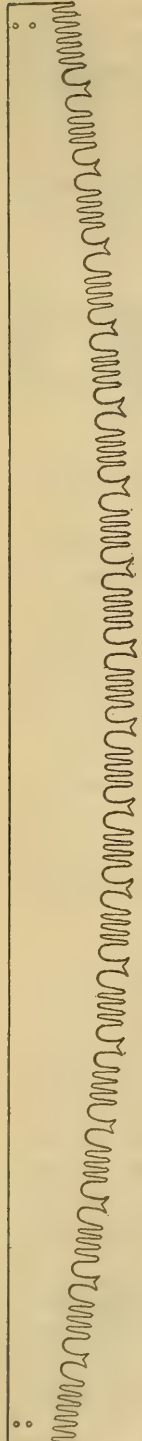


FIG. 5.—Bucking saw.

side and then to saw on a slant, taking as much wood as possible on the convex side.

STUMP HEIGHTS.

Frazier Curtis, writing on stump heights in 1900, implies that the height of stumps in this region at that time ranged from 3 to

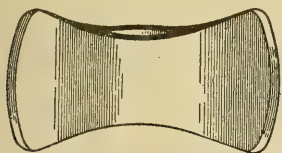


FIG. 6.—Swamping ax.

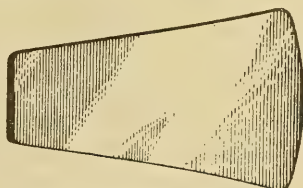


FIG. 7.—Bucking wedge.

5 feet, but that in times past it was customary to cut much higher stumps, some of them running as high as 20 feet. He speaks of one 160-acre tract where 2,000,000 feet of sound material had been left in high stumps.

The practice at the present time is to reduce the height of stumps to the lowest point practicable. The fact that most companies practice long butting rather than cut high stumps in questionable timber, which means an extra cut, indicates that they prefer to err on the side of labor rather than wood waste. Not all companies are so careful, since operations can be found where the stumps are higher than strict economy seems to require.

As to the average height of the stumps cut in this region, it is difficult to generalize. Taking it straight through, they probably range between 3 and 5 feet. Small, second-growth Douglas fir stumps are cut as low as 2 feet. Old hemlock stumps are frequently cut at seemingly wasteful heights, especially when the company does not follow the practice of long butting. It is not unusual to see old-growth cedar cut higher than 5 feet from the ground.

The stump heights on timber sales in the national forests of the region are a little lower than those in private cuttings of a like character. The clause relating to stump heights in a contract dealing with a recent sale of a body of timber in the Olympic National Forest reads:

Stumps will be cut so as to cause the least possible waste, and not higher than 24 inches on the side adjacent to the highest ground, except in unusual cases, when, in the discretion of the forest officer in charge, this height is not considered practical.

LOG LENGTHS.

Douglas fir is well adapted to the manufacture of long timbers, and supplies a large share of the demand for such material. This

has resulted in a type of mill designed to handle long logs economically. The methods of logging make it possible to handle relatively long logs more cheaply than short lengths, where the volume of such logs does not tax the equipment. The general tendency is to increase the length of the logs cut.

Logs, like lumber, are cut into even lengths, ranging from 16 to 60 feet and sometimes longer. The customary lengths range from 24 to 40 feet. Laying aside the factors of volume, grade, and utilization—woods and mill—logs as a rule should be cut about 40 feet in length, which is probably the most economical length to log and manufacture. Not infrequently the economical handling of timber of large diameter makes it necessary to cut some logs 24 feet in length. In cutting timber so that logs of the highest grade will result or so that the logs will contain the minimum amount of defective or broken material, it is necessary to vary the lengths, some of them running as short as 16 feet. On the other hand, logs up to 90 feet or more in length may be utilized in the manufacture of long timbers.

Logs longer than 40 feet bring special prices in the log market, because timber adapted for long logs of a certain grade is relatively less plentiful, and the seller may sacrifice grade and scale in addition in some cases to the extra expense of logging them. One manufacturer on the Columbia River, when paying \$9 per 1,000 feet for No. 2 Douglas fir logs of the usual lengths, paid the following prices per 1,000 feet by lengths for No. 2 Douglas fir logs 26 inches in diameter: Fifty to sixty feet, \$11; 62 to 70 feet, \$13; 72 to 80 feet, \$15; 82 to 90 feet, \$17.

It has been pointed out that it sometimes costs more to log long logs. For example, in one case a logging contractor was receiving in 1916 the following prices per 1,000 feet by lengths from a timber company for delivering logs from the stump to the raft: Forty-eight feet and under, \$6.52; 48 to 60 feet, \$7; 62 to 70 feet, \$8.50; 72 to 80 feet, \$9.50. The railroad haul from the landing to tidewater is 35 miles, the greater part of which is over a common-carrier railroad.

While some companies find it more expensive to handle logs 50, 60, 70, and 80 feet in length than logs of the usual lengths, largely because of the broken character of the ground they are operating in and the fact that the logs must be transported over a common-carrier railroad, some companies that own and operate all the railroad used in the transportation of their logs can handle long logs more economically than short ones (see "Ground Yarding Output"). These companies yard logs from 60 to 80 feet or more in length, or the entire bole of the tree to a top diameter of from 6 to 8 inches. The average length of the logs handled in a year by one company, operating in

good ground and second-growth timber along the Columbia River, was 60 feet.

Long logs can be cut into shorter lengths at the landing, boom, or mill with a power machine more economically than in the woods with a crosscut saw, and special orders for unusual lengths can more readily be filled.

LONG BUTTING.

Some trees are defective at the base, the defect consisting of rot, shake, and pitchy material extending 6 feet or more up the tree. These defective ends will make little lumber, so little or no scale is given them. To include them with the butt logs would be poor economy, since it costs practically as much to log and saw defective as sound material, particularly in the case of operators who haul over a common-carrier railroad. This has resulted in the practice of bucking off that portion of the tree which in the judgment of the log marker is defective. The practice is known as long butting.

Old hemlock trees frequently need to be long butted, the defect at the base—rot, shakes, and checks—destroying the utility of the butt logs, though these defects are not so common or so injurious in western hemlock as in the eastern species. The operator can not afford to take any chances in the utilization of hemlock. Sound hemlock logs sold in 1916 from \$5.50 to \$6.50, in rare cases \$7, per thousand feet, a price that about equals the price of the lowest grade of Douglas fir; so there is a comparatively small margin of profit, sometimes no margin. Then, too, if hemlock that has not been long butted is dumped into the water, driven, rafted, and towed some distance, or stays in the water any length of time, a portion of the butt logs will be lost through sinking or straying. The loss because of hemlock "sinkers" will vary. If no preventive measures are taken, such as long butting, cutting long-butt logs, "swinging" the butt logs in the raft, etc., the loss may amount to 10 or 15 per cent.

BREAKAGE.

With the felling of the first tree the logger was confronted with a problem of breakage, which was to remain to a great extent unsolved to the present and reach its most aggravated form on the Pacific coast.

No comprehensive study of breakage as it relates to this region has been made. Few companies have seen fit to study the losses that result. Different men have different ideas as to what the percentage is in the region as a whole or in a given camp. One head buckler puts the loss at 30 per cent of the timber felled, taking it straight through, 60 per cent of this loss being due to carelessness. Others estimate the breakage at from 5 to 15 per cent of the total merchantable stand.

The truth is, no one knows; no one has sufficient data on which to base a judgment. In some cases, because of the character of the ground and the size of the timber, the amount of breakage is so small that one may safely estimate it at 2 or 3 per cent; in others, where the slopes are rocky or broken up, it is so large that one feels justified in guessing it at 40 or 50 per cent. At one camp, where the timber is large and the ground is rough, in felling 1,000 thousand feet of timber, the breakage amounted to 9 per cent. At another camp the breakage on a 40-acre tract was 37 per cent. Taking it straight through the region, breakage probably runs from 10 to 15 per cent of the merchantable stand, being higher than this where the timber is large and defective or fire killed, or where the ground is particularly steep, rough, or rocky. Whatever the amount is, it will probably increase as operations are extended into the steeper places, unless different methods are used.

Waste resulting from breakage may be divided into three classes:

- (1) That which can not be helped.
- (2) That which is necessary to save more valuable timber.
- (3) That which is preventable.

Just how much of the present breakage is preventable, no one is in a position to estimate confidently. Furthermore, it is not an easy matter to get at. Some men, however, think the amount in the aggregate is large.

It should not be inferred from anything that has been said that operators are not aware of this condition, and that they are not doing what they think should be done to reduce breakage to the minimum. Most of them aim to employ experienced head buckers and fallers; have the windfalls bucked ahead of the felling; have no timber felled across unbucked timber; have the fallers resort to wedging when it is necessary and practical; have two or three fellings made in dense stands when the logs are bucked in short lengths; have the larger and more valuable species felled first; have a bed made for the large timber when it is necessary and practical; and, when there is danger of a tree landing on a stump, have the stump bowled off on one side, or have poles laid against the stump, so that the tree landing on the stump will be sheered off and the force of the fall broken.

Fallers, however, often become careless, especially under a bonus system. Here, as in every other line of work, a check made occasionally is conducive to higher efficiency. A casual inspection, desirable as it may be, is not sufficient. An intensive inspection could be made by a head bucker and scaler working together to keep a check on the fallers and buckers and to collect data as a basis for comparing the breakage under different conditions.

The cost of unusual care may more than offset the gain resulting from reduced breakage. Generally speaking, there should be a rela-

tion between the loss through breakage and the value of the stumpage; loss through breakage should decrease as stumpage increases in value. In this connection it should be remembered that as a rule it is the top log or logs that are broken, and that these logs are relatively less valuable. On the other hand, breakage increases the cost of felling and bucking, also the cost of several other departments of the logging operation.

If it is true that operators who have purchased their timber outright not infrequently lose money through careless felling, it would seem that the Forest Service in basing the selling price of a block of timber on the amount logged and scaled should make sure that purchasers of National Forest timber exercise reasonable care in felling it. Forest Service timber sale contracts deal in a general way with the matter of felling, and on some features of the work state specifically what shall or shall not be done. Where the contract is not specific, the assumption is that the purchaser will do the work in accordance with the practice of progressive operators who are working in similar shows and own the timber.

WASTE IN BUCKING.

IMPROPER TRIMMING LENGTHS.

It is necessary to cut logs a few inches longer than the standard: (1) Because it is not possible for buckers to cut exactly at right angles, especially in large timber and on rough ground; (2) because logs are often damaged on the ends when being yarded, roaded, chuted, or driven, particularly in the last two methods of transportation; (3) to facilitate the work of the trimmer man at the mill, and to allow for the kerf cut by the trimmer saws. As a rule, the following allowances for trimming should be ample: Logs up to 32 feet in length, 5 inches; 32 to 48 feet, 7 inches; 48 feet and upward, 9 inches. In general, the allowance may be less in small than in large timber, less on good than on bad ground.

Workmen frequently become careless and cut the logs into improper lengths. This is due, for the most part, to the use of a measuring pole of the wrong length, the careless use of the pole, and the use in some places of a pole instead of a tape. Where less than 2 inches is left for trimming, 2 feet of log length may be lost at the mill; while on logs that are several inches too long, the loss is also considerable. Though no systematic study of this matter has been made, there are good reasons for thinking that the loss to the industry is worth considering. The measuring of 523 Douglas-fir logs at a mill on Puget Sound showed that only 139 logs were of the proper length, that 24 were too short, and that 360 were from 4 to 18

inches too long. The loss on these logs because of improper lengths is estimated at 13,230 feet, or 1.7 per cent of the scale. Assuming that the average value of the logs per thousand feet was \$9, the total loss on the basis of 523 logs was \$119, or \$0.15 per thousand feet.

Employing an efficient head buckner undoubtedly results in a saving. Often a buckner has a measuring stick of the proper length, but, finding it takes more work to clear the brush away from a log or to do some extra wedging or undercutting, cuts the log longer or shorter than it should be. One of the most progressive operators of the region, finding that his company was sustaining considerable loss because of improper lengths, gave his head buckner an assistant, so that the log lengths could be marked off with a tape line. It was a very difficult bucking show.

DISREGARD OF QUALITY.

The buckners should exercise care in apportioning the boles of the trees, so that logs of the highest grade, or logs that will yield the largest amount of high-grade lumber with the minimum of trimming waste, will be obtained. It is no uncommon sight to see logs graded and sold as No. 2, or merchantable, which would have been graded as No. 1 logs had they been cut a few feet shorter. As No. 1 logs may be worth \$12 per thousand feet when No. 2's are worth \$9, it is clear that too much attention can not be given the matter of bucking for quality.

Proper supervision will help out greatly. Most buckners have good intentions, but are not well informed about log grades.

MISCELLANEOUS CAUSES.

Considerable waste not infrequently results from not utilizing as much of the tops as is practical. The bucking of crooked trees in the wrong place also results in waste, but in this region, where the trees are large, the amount is small. The same thing is true of the waste that results from cutting too far above or below the crotch of forked trees. Sawing too far below the break in broken timber may result in a small loss. The major portion of waste in bucking is probably due to inefficient or careless buckners. In large timber and rough ground failure to take out the bind of trees through a properly located initial cut, indifferent wedging, and carelessness in putting in props results in a comparatively heavy loss, logs not infrequently being slabbed or split for a considerable length. Splitting in hollow-butted cedar logs not infrequently results from cutting them too short or from not providing sufficient sound material to hold them intact.

OUTPUT.

An analysis of a number of felling and bucking cost statements indicates that the output of a set of fallers, as a general thing, ranges between 25,000 and 30,000 feet net scale per day. Some companies are averaging as high as 35,000 feet per day to a set of fallers; a few, 40,000 feet or more. Other companies are not averaging as much as 20,000 feet.

Two or three buckers are generally required with a set of fallers. It is not unusual to find three. If there are very few windfalls and the slope of the ground is fairly regular, so that little undercutting is necessary, two will be able to do the work. In good ground, where exceptionally long logs are cut, one bucker may be enough. The output of buckers ranges between 10,000 and 15,000 feet net scale per day, averaging about 12,000 feet. It would seem, judging from an analysis of cost statements, that the output in many cases is less than 10,000 feet. In one large camp, where the logs averaged about 36 feet in length and 1,800 feet in volume, and the ground was badly broken up, the average output per bucker per day over a period of 2 years was 9,500 feet.

TOOLS AND EQUIPMENT.

SAWS.

Two falling saws are required for each set of fallers, one for use while the other is being filed. The lengths range from $7\frac{1}{2}$ to 10 feet, depending on the size of the timber. Eight feet is probably the most common length. Of course it is necessary in many cases to have a few 10 or 12 foot saws on hand for the larger trees. Two bucking saws are required for each bucker, their length varying with the size of the timber, $7\frac{1}{2}$ feet being the common length. There must be some extra falling and bucking saws on hand, the number depending on the size of the operation.

The net prices in March, 1915, of a grade and pattern of falling and bucking saws used by a large number of Pacific coast logging operators were as follows:

Length of saw, feet.	Net price, each.
6 -----	\$5.00
$6\frac{1}{2}$ -----	5.67
7 -----	6.30
$7\frac{1}{2}$ -----	7.00
8 -----	7.60
$8\frac{1}{2}$ -----	8.30
9 -----	9.14
$9\frac{1}{2}$ -----	9.96
10 -----	10.77
11 -----	12.60
12 -----	14.49
14 -----	18.46

These prices are a little high, which is due to present economic conditions. The falling saws are 13 gauge on teeth, 17 gauge on back; the bucking saws are 13 gauge on teeth, 18 gauge on back. Detachable wooden handles (fig. 8) are used. The reversible Pacific coast type costs about \$0.65 per pair; the common type, \$0.35 per pair.

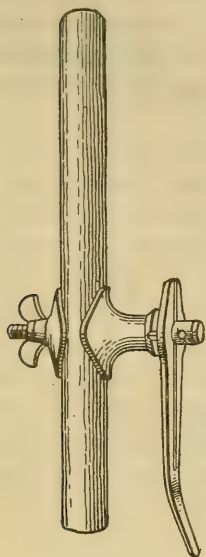


FIG. 8.—Saw handle.

AXES.

One falling ax is required for each faller; one swamping ax (fig. 6) for each buckner. The head of the ax used in the region is double-bitted; that is, has two cutting edges. Falling-ax heads vary in weight from $3\frac{1}{2}$ to $4\frac{1}{2}$ pounds; swamping-ax heads from 4 to 5 pounds, according to the character of work and the personal ideas of the workmen. The handles, which are made of straight-grained second-growth hickory, are straight and from 38 to 42 inches in length. The net price of the best quality of falling ax ranges from \$11 to \$12 per dozen; of the swamping ax, from \$10 to \$11 per dozen. The handles cost from \$2.50 to \$3.50 per dozen.

STEEL SLEDGES.

A steel sledge is used by each faller and buckner for driving wedges. The heads of those used by the fallers weigh about 10 pounds; those used by the buckners, 8 pounds. The cost of the heads ranges from \$0.25 to \$0.30 per pound; of the handles, from \$2 to \$2.50 per dozen.

STEEL WEDGES.

In well-equipped camps, each set of fallers has 4 or 5 steel falling wedges, and each buckner 4 or 5 bucking wedges, weighing from 6 to 8 pounds each. The cost of the best steel wedges is about \$0.25 per pound.

SPRINGBOARDS.

In other than small second-growth timber and good ground each set of fallers is equipped with two spring, or chopping, boards which serve as platforms for them to stand on when undercutting and sawing. These boards are 4 or 5 feet long and 8 inches wide, tapering from 1 inch in thickness to 2 inches at the end, which is fitted

with an iron spur. The springboard, with the spur uppermost, is thrust into a horizontally based notch cut into the tree. When the faller's weight is applied to the outer end of the board the spur is forced into the wood, preventing the board from slipping, keeping it level, and allowing it to be swung around with the iron spur serving as a hinge. The boards are made in the camps, generally by the blacksmith or filer, of maple or Douglas fir, generally the former. The irons or spurs (fig. 9), as a rule, are made by the camp blacksmith, although they may be purchased for about \$1.25 per set.

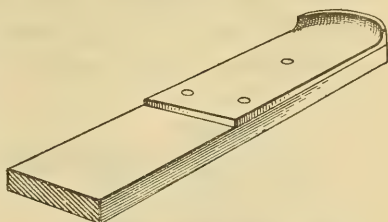


FIG. 9.—Chopping board iron.

UNDERCUTTERS.

It has been pointed out that in cutting trees into log lengths it is not infrequently necessary to put a cut in on the underside. To assist in holding the saw against the wood while undercutting is in progress, an undercutter may be used. There are several types on the market, one of which is shown in figure 10. The commonest practice is to insert the bit of an ax in the tree in such a way that the spring in the handle can be utilized to hold the saw to the cut.



FIG. 10.—Undercutter.

SPECIAL EQUIPMENT.

TREE FALLER.

Among the recent innovations in logging equipment is the tree faller or jack. Its primary object is to enable timber fallers to throw trees in any direction regardless of the lean, thus making it possible to save considerable timber from breakage. Furthermore, if the machine is adapted to ordinary conditions, and the company manufacturing and selling it claims that it is, it will do away with wedging, which is a time and energy consuming operation.

As is shown in figures 11 and 12, the device embodies the simple principle of arms working on a fulcrum and spread through the agency of a slow-moving screw operated by a hand lever. It is made of special alloy steel, the required lifting power being enormous.

A roller thrust bearing reduces the friction. Separate oscillating plates are used to increase the compression surface. The opening between the jaws when the screw is fully extended is 7 inches.

The device complete, including the lever, weighs 166 pounds. However, it is of a take-down design, so that this weight can be divided about equally between the two fallers. Figure 13 shows the

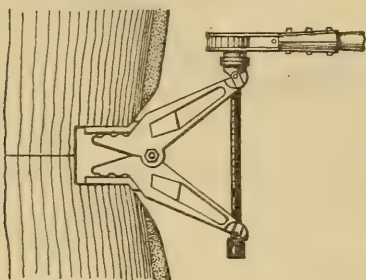


FIG. 11.—Method of inserting tree faller in notch.

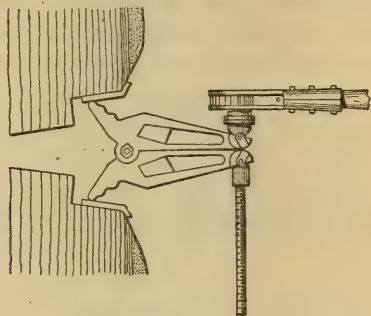


FIG. 12.—Cut opened about 7 inches with tree faller.

special pack boards used in carrying the parts in the woods. The amount of time consumed in taking down or assembling the machine is insignificant.

Figure 11 shows the method of inserting the jack in place on the oscillating plates, also the jack ready for operation, with the roller on the jaws nearest the fulcrum set in the third cavity of the plate.

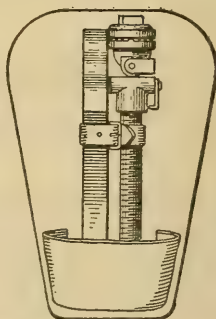
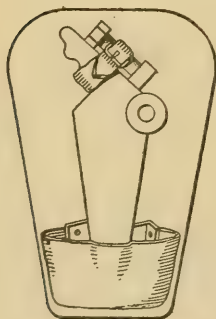


FIG. 13.—Method of carrying tree faller in the woods.

At this point of the operation the strain is greatest. Figure 12 shows the cut opened 7 inches with the end roller (the one farthest away from the fulcrum) set in the third roller cavity of the plate. At this point the strain is least.

The manufacturers of this device have spent several years in experimental work, building several different

types with several different kinds of steel. They now feel that the machine has passed the experimental stage. The principal difficulty has been in finding a steel that would stand the very trying service demanded of it. Jacks built of other steels than the kind now used stood the test for a while, and then broke under strains seemingly no more severe than those they had successfully withstood. It is to be hoped that the jack as now constructed will measure up to

the expectations of the manufacturer; for, if it does, it will make a great saving in timber and human energy, also a reduction in logging costs.

The possibilities of the device were demonstrated before the members of the Pacific Logging Congress at Eureka, Cal. An 8-foot redwood, having an adverse lean of 5 feet, was thrown by the jack in a direction opposite to the lean in 13 minutes, notwithstanding the fact that 10 inches of "wood" was left uncut, and had to be broken by the power of the jack before the tree could fall. Other demonstrations have been made with equal success. One operator, working in a hard show, has used an earlier model for about 2 years with very satisfactory results. It is said that in a competitive test one set of fallers, aided by a jack, felled a $6\frac{1}{2}$ -foot tree having a lean of 6 feet in $3\frac{1}{2}$ hours, while another set, working with wedges, required $13\frac{1}{2}$ hours to fall a $5\frac{1}{2}$ -foot tree having a lean of 5 feet.

PORTABLE DRAG SAWS.

The portable drag saw is operated with either steam or gasoline, and is adapted for cutting saw logs, shingle bolts, cordwood, fuel for logging engines, etc. It can be operated by one man. A number of operators find its use profitable in bucking up fuel wood for logging engines. One machine may be used for two engines where they are located near one another. Where the ground is not too rough and the timber not too large, it may be used to advantage in bucking up trees into log lengths at the landings, especially where the timber is roaded to the landing.

Some think that the gasoline drag saw is not so well adapted for use by loggers as the steam saw, since it has not the capacity of the steam saw of the same weight and is more complicated in its make-up. However, improvement in gasoline drag saws has reduced the weight and increased the capacity so that they are now being universally installed, replacing cutting of fuel by man power. A gasoline saw is easily portable and can be taken anywhere by two men; it is not dependent upon a separate power plant and does not have to have the log moved to it for each cut. One man operates the saw and moves it to the log.

One steam saw has a $3\frac{1}{4}$ -inch cylinder and a 30-inch stroke, running 225 strokes per minute. This machine is intended for use with a 6-horsepower vertical boiler and may be carried on a sled or low-wheel truck. The steam is conveyed in a $\frac{3}{4}$ -inch pipe, joined in 8 or 10 foot lengths with flexible couplings. Steam may be conveyed successfully in this way for 300 feet. One hundred pounds steam pressure is ample for successful operation. Steam may also be taken from logging engines or other boilers through a similar system of piping. A hand rope gives the operator complete control of the saw when it

is entering a log or when making the final light strokes in finishing a cut. When running at a normal speed the machine will cut a 30-inch log in 2 minutes, a 72-inch log in 14 minutes.

The price of this steam saw in 1916 was \$200 f. o. b. Portland, including one 6-foot saw, but not the boiler. It weighs from 235 to 250 pounds. The shipping weight is 350 pounds.

One gasoline drag saw cut off logs in the water at the following rates:

Diameter of logs, inches.	Minutes.
50-----	11
51-----	13
54 (pitchy)-----	16
56-----	14
59-----	15
60-----	23

AVERAGE INVESTMENT IN EQUIPMENT AND SUPPLIES.

The investment in regular felling and bucking equipment, as shown by the inventory, at one operation cutting about 450,000 feet per day amounted to \$1,442. This was the depreciated value of the equipment at the time the inventory was made, so that the first cost must have been considerably higher. Furthermore, the fallers filed their own saws, making it possible for the company to get along on less equipment than otherwise would be the case.

Table 6 gives the estimated average fixed investment in felling and bucking equipment and supplies at camps of different capacities. Freight is not included.

TABLE 6.—Average investment in felling and bucking equipment and supplies.

Item.	Capacity of camp per day.													
	50,000 feet.		75,000 feet.		100,000 feet.		125,000 feet.		150,000 feet.		175,000 feet.		200,000 feet.	
	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.	Number.	Cost.
Felling saws and handles..	7	\$56.90	10	\$77.85	13	\$101.40	16	\$124.95	18	\$140.65	21	\$164.20	23	\$179.90
Bucking saws and handles..	18	129.34	25	179.36	32	224.20	39	273.44	45	314.99	52	363.35	58	404.90
Felling axes and handles..	7	10.00	10	13.90	13	16.80	16	21.70	18	24.30	21	28.20	23	30.80
Bucking axes and handles..	10	13.60	14	14.80	18	24.00	22	25.70	25	33.10	29	38.30	32	42.20
Felling sledges and handles.....	6	20.40	8	26.90	10	33.60	12	40.20	13	43.50	15	50.10	16	43.40
Bucking sledges and handles.....	10	27.60	14	38.40	18	49.20	22	60.00	25	68.10	29	78.90	32	87.00
Felling wedges.....	15	30.00	21	42.00	27	44.00	34	68.00	39	78.00	45	90.00	50	100.00
Bucking wedges.....	32	56.00	46	80.50	60	105.00	74	129.50	86	150.50	100	175.00	102	196.00
Grindstones.....	1	6.00	2	12.00	2	12.00	3	18.00	3	18.00	4	24.00	4	74.00
Filing tools and equipment.....	...	20.00	...	20.00	...	20.00	...	20.00	...	30.00	...	30.00	...	30.00
Oil, files, etc.....	...	10.00	...	15.00	...	20.00	...	20.00	...	20.00	...	20.00	...	20.00
Total cost.....	...	379.84	...	520.71	...	650.20	...	801.49	...	921.14	...	1,062.05	...	1,208.20
Total weight (lbs.).....	...	1,500	...	2,000	...	2,500	...	3,000	...	3,500	...	4,000	...	4,500

COST.

The cost of felling and bucking in the region ranges from \$0.45 to \$1 per thousand feet, averaging about \$0.65. Cost data dealing with 40 large camps indicate that the average costs per thousand feet by districts are as follows:

Puget Sound	\$0. 68
Grays Harbor	. 62
Willapa Harbor	. 62
Columbia River	. 70

FACTORS INFLUENCING THE COST.

Considering how much the cost of felling and bucking varies in different camps, to estimate it in a given case is no simple matter. Furthermore, it varies in the same camp at different times. At one camp it decreased steadily from \$1.10 to \$0.50 per thousand feet in five years, presumably because of increasing efficiency in the management; at another, it increased more or less steadily from \$0.55 to \$0.82 per thousand feet, largely because of the changing character of the show.

In a general way the following factors influence the cost of felling and bucking:

- (1) Efficiency of labor and management.
- (2) Scale of wages.
- (3) Weather conditions. There is no doubt that the output of fallers and buckers varies with the weather and the length of the working day as fixed by light conditions. In timber appraisal not much weight need be given this factor. In collecting cost data and in making studies to arrive at standards to be used with bonus systems or systems for checking up the daily output of the workers considerable weight should be given it where the studies cover a relatively short period of time.
- (4) The size of timber. It would seem, other factors being excluded, that the output of a set of fallers and buckers should, within certain limits, increase with the size of timber, both in height and diameter. Obviously, the output will be larger where the timber is relatively tall than where the opposite is the case. Then, too, the diameter seems to affect the output, fallers feeling that they secure the best results in timber that runs from 30 to 40 inches in diameter at breast height. If the factors of breakage and defect could be eliminated, they would probably do their best work in slightly larger timber.
- (5) The percentage of breakage, the density of the stand, and the species of timber. Of these three factors, breakage is by far the most important. It is obvious that the output will be less where the percentage of breakage amounts to 40 per cent than where it amounts to

only 3 per cent. It would seem that the output should be less in light stands than dense ones, since more time is lost because of travel in a light stand than in a dense one, especially where the ground is steep and brushy. Of course, the opposite may be true when, because of the density or mixed character of the stand, two or more fellings are made. The difference in the output because of different species amounts to little or nothing, except as different species of the same diameter vary in volume, percentage of breakage, or percentage of defect. For example, the output of a set of fallers when working in western red cedar will be from 15 to 20 per cent less than when working in Douglas fir of the same diameter, because the volume of the trees will be less, breakage will be higher, and the percentage of merchantable timber will be less.

(6) The percentage of defect. Defect in timber increases the costs in the same way as breakage. This factor has been growing more important, and it will continue to grow in importance as utilization in the woods increases. Its effect in pushing up the cost is shown by the following case, which is exceptional: The fallers were paid (contract work) for 6,210,000 feet, gross scale; the buckers (contract work) for 4,773,000 feet, gross scale; while the logs hauled and utilized scaled 2,498,000 feet net scale.

(7) The length of the logs. As a rule, the output of bunkers is larger when long lengths are cut.

(8) The amount of windfalls. It has been pointed out that in order to keep the percentage of breakage as small as possible, it is necessary to buck the windfalls before the timber is felled. As a general thing, the merchantable material obtained from this class of timber is small, hence the cost of bucking varies with the character and number of windfalls.

(9) The steepness and roughness of the ground. As the ground becomes steeper and rougher, the percentage of breakage, the time lost in traveling from one tree to another, and the hazards of the work, also the amount of wedging, undercutting, and propping, increase. All these tend to reduce the output.

(10) The amount of brush. At times the brush is so thick that the fallers have to swamp out a trail in going from one tree to the other.

(11) The distance of the work from the camp. Time consumed and energy expended in getting to and from the work have an effect on the output.

EMPLOYMENT AND PAYMENT OF LABOR.

The basis of employment and payment of labor in this region is generally a 10-hour day, with a charge for board. Head buckers are sometimes paid by the month.

The wages paid the different members of the felling and bucking crew vary. During certain years, or parts of years, wages are higher than in others. At a given time some camps pay 8 to 10 per cent more per man than others. Then in the same camp some of the men, because of special fitness, receive a larger compensation than the others. For these reasons it is difficult to state the average wages paid the different members of these crews during the past several years.

The following list is intended to approximate the wages—average, high, and low—paid the members of the felling and bucking crews by the logging companies in the region during the six years ending 1916:

Position.	Wages per day.		
	Average.	High.	Low.
Head buckler.....	\$3.50	\$3.75	\$3.25
Head faller.....	3.50	3.75	3.25
Second faller.....	3.25	3.50	3.00
Bucker.....	3.25	3.50	3.00
Filer.....	3.75	4.00	3.50

The wages given in the column headed "Low" do not represent the lowest wages that have been paid. Camps that have paid the wages included in column headed "Average" paid the following wages in October, 1915:

	Per day
Head buckler.....	\$3.00
Head faller.....	3.00
Second faller.....	2.75
Bucker.....	2.50
Filer.....	3.00

The scale of wages for head buckers and filers is less standard than for the other members of the crews, hence the wages listed for them are more or less deceptive. Then, too, head buckers are paid more now than they were two or three years ago, some of them now being paid \$5 or more per day. A good head buckler can easily earn this amount. Filers are paid from \$3.50 to \$5.50 per day, depending on their ability, the character and amount of work, and whether they are working as head or second filers.

A small percentage of the operators do the felling and bucking by contract, payment being made on the basis of the thousand feet net or gross log scale. The contract may be let to one man who employs labor by the day to do the work, or directly to the workers. Contract felling and bucking has not been popular in this region, chiefly for the following reasons: (1) The character of the work varies so much

that it is difficult for the contracting parties to get together on terms with sufficient security; (2) breakage of timber in felling and bucking is likely to increase; (3) disputes may arise because of the way and time logs are scaled; (4) it does not work well to have two crews in a camp under different heads, which may result in a disparity in the wages paid or the hours worked, and thus breed discontent; (5) there are phases of the work that the contractor may not look after so well as an employee of the company.

A few camps use bonus or profit-sharing systems in connection with the felling and bucking. Two systems are in use. One consists of setting output standards for the fallers and buckers, and allowing each faller and bucker who has been in the employ of the company a certain length of time a certain amount per thousand feet in addition to the regular wage for every thousand feet felled and bucked in excess of the standard in a certain length of time, generally a month. One company that uses this system in three large camps, feels that it is a success, since it has enabled them to reduce their felling and bucking costs materially and to secure a knowledge of what fallers and buckers can and should do. Another company used this system for three months and went back to the straight wage system. The results obtained in the way of increased output were not disappointing. The trouble was that the workmen paid too much attention to the quantity and not enough to the quality of the work.

The other bonus system consists of setting a labor cost per thousand feet, and allowing each faller and bucker who has been in the employ of the company a certain length of time—say, 60 days—a portion of the difference between the actual and standard labor cost per thousand feet, on the basis of the number of days each has worked. In other words, if the total wages paid give an actual average cost per thousand feet of \$0.55 and the standard cost per thousand feet is \$0.65, the difference is divided between the fallers and buckers on the basis of the number of days they have worked.

One of the objections to bonus systems is that they tend to increase breakage. It would seem, however, that with proper supervision this objectionable feature could be practically eliminated.

SUPPLIES AND REPLACEMENTS.

It is impossible to say with any degree of certainty how much it costs per thousand feet for supplies and the replacement of equipment. The amount, however, is small and few logging companies have deemed it advisable to classify their logging costs in such a manner as to make this information available. It is close to \$0.03 per thousand feet. The writer has seen annual segregated cost statements that indicate it to be as low as \$0.01 per thousand feet; others as high

as \$0.04 per thousand feet. To get a correct figure, one would have to keep a careful record for three or four years. By no other means would it be possible to brush out the errors that creep into inventories of used equipment. Even a figure secured in this way would not fit all conditions. The above figure is intended to take care of the oil used in connection with the operation of felling and bucking and the supplies used by the filer, as well as the saws, axes, sledges, wedges, etc., used by the fallers and buckers.

The following statement which gives the estimated cost of equipment and supplies worn out, lost, or consumed in connection with the work of one set of fallers and three buckers in a season, indicates the probable life of the different kinds of equipment used. The following assumptions were made: (1) That one set of fallers, working 25 days per month for a season of 8 months, will fell 5,000,000 feet of timber; (2) that three buckers will be necessary to buck 5,000,000 feet of timber in addition to the down timber in the same period.

Equipment and supplies used up in a season.

Item.	Cost.	
	Unit.	Total.
2 falling saws.....	\$7.20	\$14.40
4 bucking saws.....	6.60	26.40
5 saw handles.....	.65	3.25
2 falling axes.....	1.00	2.00
3 swamping axes.....	1.00	3.00
40 1-pound falling wedges.....	.25	10.00
60 1-pound bucking wedges.....	.25	15.00
1 10-pound falling sledge.....	3.00	3.00
3 8-pound bucking sledges.....	2.40	7.20
2 dozen axe and sledge handles.....	3.60	7.20
2 iron shoes (springboard).....	.60	1.20
Oil and supplies.....		50.00
Total cost.....		142.65
Cost per thousand feet.....		.0284

FILING.

In times past, the fitting of the saws was done by the fallers and buckers. Now it is ordinarily done by filers who are regularly employed at this work. All camps employ one filer; the larger camps, two. If the operation is large and scattered, three filers are sometimes necessary. In a general way, one filer can do the work in a camp having an output of 150,000 feet per day or less; two are necessary if the output exceeds this figure.

The number of saws that a filer should sharpen in a day varies with the ability of the filer, the character of the chance, and the length of time the saws are used before they are filed. Taking it straight through, a filer sharpens from 10 to 12 saws per day. The number is frequently as high as 16 saws per day.

There is no rule governing the length of time a saw, falling or bucking, should be used before it is refitted. The time depends to a great extent on those using the saw, also the chance it is used in. Sometimes it is filed every day. Possibly both classes of saws are filed every one and one-half days on the average.

In addition to fitting the saws used by the regular fallers and buckers, the filer fits the saws used by the wood buckers employed with the yarding, loading, chunking-out, and scraper donkey crews.

COST OF SPECIFIC CASES.

The following gives the cost of felling and bucking at several camps. They are typical of most of the conditions in the region.

(1) Cost of felling and bucking on the west foothills of the Cascades in Oregon in 1911.

The topography was rather rough, both in major and in minor features. Slopes of from 30 to 70 per cent were not uncommon. Much of the area would be considered a fair chance.

The timber consisted of a heavy stand of very defective Douglas fir in mixture with a small percentage of hemlock and cedar. Out of a gross stand of 80,000 feet or more per acre only about 50,000 was hauled out. The logs averaged about 1,400 feet in volume.

For a long time the company allowed the foreman or fallers to decide, from their general appearance, what trees it would pay to fell. This resulted in a large proportion of the stands being left unfelled, the amount ranging from practically nothing on some acres to 30,000 feet or more on others. The leaving of so much timber seemed like waste to some of the members of the company, and cleaner cutting was tried. Some areas were cut over the second time, and the timber proved to be nearly as sound as that secured at the first cutting. The management now feels that it is impossible to determine which of the timber should be utilized without felling and bucking practically all of it, and this is the policy they are now following.

The cost per thousand feet in the year 1911, when practically everything was felled, was as follows:

Felling, labor.....	\$0.437
Bucking, labor.....	.499
Supplies and equipment.....	.030
Total cost.....	.966

This cost is based on the mill scale, which was close to the lumber tally. It includes the wages of the filer, scaler, and marker. The fallers were paid from \$0.15 to \$0.17 per thousand feet for felling, the bucker from \$0.15 to \$0.21 per thousand feet for bucking, regardless of whether the logs were sound or not.

It cost about \$0.25 more per thousand feet when practically everything was cut than it did when a large proportion of the stand was left as presumably worthless.

(2) The labor cost per thousand feet, selling scale, for felling and bucking at a camp on the flat to the west of the Cascades in Washington, based on a period of six months in 1912 and an output of 25,000,000 feet.

The ground was practically level and quite free of brush and down timber. Few hummocks, pot holes, or troublesome ravines were encountered.

While the timber was relatively small, the stand was dense, cutting out from 85,000 to 90,000 feet per acre. It averaged about 30 inches in diameter, breast high, and was of good height. The logs averaged 550 feet in volume and ranged from 32 to 40 feet in length. The timber was practically sound, the breakage amounting to not more than 5 per cent.

Five sets of fallers worked with the three sides, averaging about 28,000 feet per set per day. Approximately three buckers worked with a set of fallers, bucking both the down and felled timber.

The average cost per thousand feet for labor amounted to \$0.49. One filer was employed. The camp foreman was directly in charge of the work, but none of his salary is included in this cost. The following daily wages were paid: Head fallers, \$3.25 to \$3.50; second fallers, \$3 to \$3.25; buckers, \$3; filer, \$3.75.

(3) Cost of felling and bucking at a camp along the Columbia River in Washington in the years 1910, 1911, 1912, and 1915.

The tract was mountainous, rough, and broken up, the slopes generally being quite steep. No rock outcrops or cliffs were encountered. There was a considerable amount of down timber and an average amount of brush.

The timber was large old-growth fir, which was cutting out from 80,000 to 100,000 feet to the acre, with about 20,000 feet of hemlock left. It was the policy of the management to cut no hemlock under 28 inches in diameter, breast high. Little fir, cedar, or spruce was left. Breakage amounted to 10 or 15 per cent. The logs averaged about 36 feet in length and 1,900 feet in volume.

The average labor cost per thousand feet in 1912, which was based on an output of 38,000,000 feet, was as follows:

Felling	\$0.168
Bucking	.382
Total	.550

The felling cost includes the wages of the fallers and one-half the wages of the filer; the bucking cost includes the wages of the buckers, head buckers, assistant head buckers, and one-half the wages of the saw filer. The following daily wages were paid. Head fallers, \$3.75;

second fallers, \$3.40 to \$3.50; head buckler, \$3.75; assistant head buckler, \$3; buckers, \$3.25.

The labor cost per thousand feet in other years was as follows: 1911, felling \$0.31, bucking \$0.46; 1910, felling and bucking, \$1.10; 1915, felling and bucking, \$0.49. In 1915 the company used a bonus system in connection with the felling and bucking.

The head buckler supervised the felling and bucking work and, with an assistant, marked the log lengths. The logs were measured with a tape. Prior to the adoption of this method the management experienced great difficulty in getting the logs bucked square off and of the desired length.

During the year the company averaged about 3 sets of fallers and about 16 buckers per day. This is 5 buckers to a set of fallers, and seems high. However, we have noted that there was a considerable amount of down timber, and that the size of the timber and the character of the ground made it a difficult and dangerous bucking chance.

(4) Labor cost per thousand feet for felling and bucking at a camp along the Columbia River in Oregon in 1911 and 1912.

The area was quite level, the surface regular, being considered one of the best ground chances in this region.

It was a second-growth forest which was cutting out about 80,000 feet per acre, the trees averaging about 28 inches in diameter breast high. From 90 to 95 per cent of the stand was Douglas fir, the rest hemlock. The timber was practically sound, and breakage did not amount to 5 per cent. The logs averaged about 60 feet in length and 800 feet in volume.

The labor cost per thousand feet in 1911 was \$0.295 for felling and \$0.227 for bucking. The felling cost includes one-half the wages of the filer; the bucking cost, the wages of the head buckler and one-half the wages of the filer. Approximately two buckers worked with a set of fallers. The following daily wages were paid: Head fallers, \$3.75; second fallers, \$3.50; buckers, \$3.25; head buckler, \$3.75; filer, \$3.50.

The labor cost per thousand feet in 1912 was \$0.298 for felling and \$0.308 for bucking.

(5) Labor cost per thousand feet for felling and bucking at a camp on the western foothills of the Cascades in Washington in 1911 and 1912.

The area covered during these two years was of mixed topography, there being good and bad chances. Some parts of the ground were quite level, with a relatively smooth surface; other parts, while quite level in general, were badly broken up by small hummocks and pot holes. Slopes of from 30 to 60 per cent were not uncommon, their surfaces varying in smoothness like the level land.

As to size, the timber could be classified as a mixture of old and second-growth stands. It was cutting out about 50,000 feet per acre, as follows: Douglas fir, 50 per cent; cedar, 45 per cent; hemlock, 5 per cent. The logs averaged about 36 feet in length and 1,000 feet in volume.

The labor cost per thousand feet was \$0.717 for felling and bucking in 1912 and \$0.644 for felling and bucking in 1911. The lower cost in 1911 was no doubt largely due to the fact that in this year the ground was more level and the percentage of cedar a little less.

In Table 7 are given the costs of felling and bucking at several camps in the region. For the most part they represent averages for a year or more.

TABLE 7.—*Costs of felling and bucking.*

Camp.	Cost per thousand feet.	Period.	Year.	General location of camp.
1.....	\$0.60	6 months.....	1913	Washington, west slope of Cascade Mountains.
2.....	.71	1 year.....	1911	Do.
3.....	.58	do.....	1913	Do.
4.....	.69	do.....	1911	Do.
5.....	.41	do.....	1911	Do.
6.....	.67	do.....	1911	Do.
7.....	.67	do.....	1911	Do.
8.....	.68	do.....	1912	Do.
9.....	.89	2 years.....	{ 1913- 1914 }	Do.
10.....	.77	do.....	{ 1913- 1914 }	Do.
11.....	.80	1 year.....	1914	Do.
12.....	.80	do.....	1913	Do.
13.....	.75	do.....	1914	Washington, west foothills of Cascade Mountains.
14.....	.72	do.....	1912	Do.
15.....	.64	do.....	1911	Do.
16.....	.52	do.....	1914	Do.
17.....	.58	9 years.....	{ 1905- 1914 }	Do.
18.....	.98	1 year.....	1914	Do.
19.....	.64	5 years.....	{ 1911- 1914 }	Do.
20.....	.60	1 year.....	1913	Do.
21.....	.60	do.....	1914	Do.
22.....	.49	6 months.....	1912	Washington, Sound region.
23.....	.68	7 years.....	{ 1907- 1914 }	Do.
24.....	.69	3 years.....	{ 1912- 1914 }	Do.
25.....	.68	1 year.....	1913	Do.
26.....	.69	do.....	1914	Washington, slopes and foothills Olympic Mountains.
27.....	.70	do.....	1914	Do.
28.....	.65	6 years.....	{ 1908- 1914 }	Do.
29.....	.68	1 year.....	1914	Do.
30.....	.49	do.....	1915	Washington, along Columbia River.
	.55	do.....	1912	
	.77	do.....	1911	
	1.10	do.....	1910	
	.81	do.....	1913	
31.....	.64	do.....	1912	Do.
	.57	do.....	1911	
	.64	do.....	1910	
	.67	do.....	1909	
	.55	do.....	1908	
32.....	.58	do.....	1907	Do.
33.....	.72	do.....	1912	Do.
34.....	.72	5 months.....	1913	Oregon, along Columbia River.
35.....	.52	1 year.....	1912	Do.
36.....	.61	do.....	1911	Do.
37.....	.80	do.....	1912	Do.
38.....	.71	do.....	1911	Do.
	.99	do.....	1912	Oregon, west slope Cascade Mountains.

PRIMARY LOG TRANSPORTATION.

TYPES OF POWER USED.

HANDWORK.

In the early history of the industry in the region hand logging was common. The timber was felled on slopes close to tidewater or some drivable stream, the logs were driven if need be, made into rafts, and towed to the mills. In British Columbia and Alaska hand logging is still practiced to a limited extent.

ANIMALS.

For many years animals constituted the only draft power used in logging in this region—first, oxen; later, horses. As long as the haul was short the ox was preferred, because it could live on coarse feed, draw heavier loads, stand rougher treatment, and required an inexpensive harness which could be made in camp. The ox does not mire so badly as the smaller-footed horse and is not excitable in difficult situations. When the hauls became long, the horse was used because it is more active than the ox. The ox, however, continued to divide the labor of transportation with the horse, the former being used to deliver the logs from the stump to the skid road, the latter to haul the logs without the use of a vehicle over the skid road to the mill, drivable stream, or railroad. Horses were introduced at about the same time as logging engines, and are still used to a very limited extent in second-growth timber. Extensive cutting will undoubtedly increase the use of horses.

The logs were first dragged out over trails, from which only such obstructions had been removed as were necessary to make the method feasible. So that it would not be necessary to move the logs over the ground for a distance greater than 300 feet, skid roads were brought close to the timber. This, however, was not practical at all times, and frequently logs were dragged over the ground for 1,000 feet or more on hand skids.

The second step was to drag the logs over skid roads, either with oxen or horses, for distances ranging up to a mile or more. The skid roads were carefully located, stumps were removed, cuts and fills made, and the roadbed leveled to give the best possible grade. Skids about 10 feet long and from 10 to 14 inches in diameter were laid across the completed grade at 10-foot intervals, and partly buried in the ground. A "saddle" was cut out of the center of each skid for the logs to ride in. On curves the outer ends were elevated slightly. On level stretches the saddles were greased to reduce friction. The logs were fastened together by means of grabs or dogs into long turns, each averaging about 1,000 feet board meas-

ure per horse. A team on a road of this character consisted of from 5 to 10 yoke of oxen or from 4 to 14 horses.

ENGINES.

The first patent on power skidding machinery in the United States was granted in 1883, and covered an overhead cableway system to get logs out of potholes and swampy places. It was tried out in the cypress forests of North Carolina, with the machines mounted on scows and floated in the bayous and sloughs. It did not completely solve the problem, since its range was limited to 700 or 800 feet. A ground yarding system was operated in a Louisiana swamp in 1889. It consisted of two large drums and an engine and boiler mounted on a scow, from which what in effect was an endless cable passed out into the forest for a distance of half a mile. This later developed into the system used on pull boats.

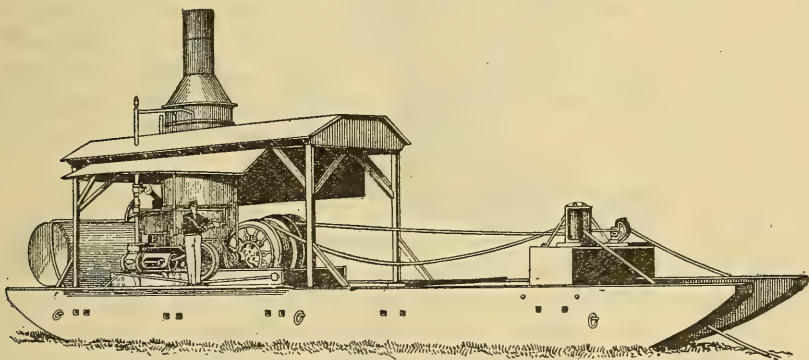


FIG. 14.—Yarding engine and sled.

Power yarding was first used in the Douglas fir forests of the Pacific coast in 1890, or one or two years before, in connection with a ground rope system. One vertical-windlass and one link-motion vertical engine, attached to an upright boiler was mounted on a sled, from which a single line was passed into the woods by horsepower. The spool was driven directly by a pinion and wheel, both of which were bevel cored. This system was first used in California about 1885.

Power yarding was superior to animal yarding from the beginning, and its popularity resulted in comparatively few horses or oxen being used in the Douglas fir region by 1900. The gradual evolution of logging engines has given the industry the compound-gearred, ground-yarding engine and the long-range, high-speed roading engine, both of which seem to have reached perfection, also fairly satisfactory overhead and high-lead logging engines, which without doubt are susceptible of further improvement.

The present ground logging engine consists of an upright boiler, two horizontal engines, two main drums, and usually a third small drum, mounted on a steel frame, all of which, in turn, are mounted on a wooden sled. (Fig. 14.) The large drums may be placed tandem, one carrying the hauling line and the other the return line. The third drum carries the straw line, which is used to run out the return or trip line, either when a new setting is being made or when roads are being changed. The engines are classified as simple and compound geared. They are further classified as yarding, swinging, or roading engines. An engine having the gears compounded is always classed as a yarding engine. One of the simple geared type is known as a yarding, swinging, or roading engine. The roading

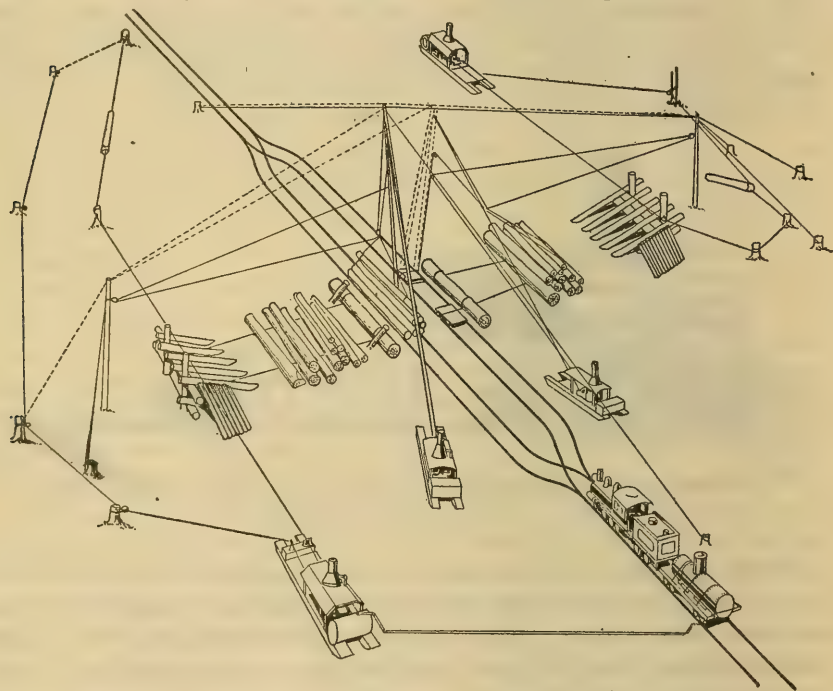


FIG. 15.—Location of improvements and equipment in ground logging.

engine has a larger drum capacity than the yarding or swinging engine. In effect, the swinging engine, an intermediate type, is a roading engine, except that it does not have such a large drum capacity.

The ground type of logging engine is brought to the site on a flat car and unloaded by means of cables and blocks, power for the latter step being furnished by the engine itself. High-lead and overhead engines, as a rule, are mounted on cars instead of sleds, and are transported from one setting to another by their own power or by a locomotive. Where railroads are not used in connection with

the logging operation, or where the yarding engines are hauling in conjunction with roading or swinging engines, yarding engines are dragged over the ground by their own lines attached to stumps along the way.

The method of operation is dependent largely on the topography of the region. The more common practice in the case of ground logging is to build a landing at a suitable spot along a railroad and to install a yarding engine at one end of it. (Fig. 15.) When the area tributary to this location is logged, the yarding engine is shifted to the opposite end of the landing. In some cases a roading engine is installed at a landing or on the bank of a drivable stream from which a pole road extends into the timber. The timber is then transported to the pole road by a yarding engine in the same manner as in the case of a railroad. It may happen that a pole road is not advisable, in which event the logs are dragged over the ground from the yarder to the landing by a swinging engine. If it is not economical to single haul the logs from the yarder to the pole road, a swing engine is used to transport them over the ground. In times past the logs were hauled over the ground to a railroad, made into turns, and dragged over the ties to the mill or water by a locomotive. This latter, however, was an unusual method.

STEPS IN THE OPERATION.

The initial step in the transportation of a log from the stump to the mill is generally known on the Pacific coast as yarding. Skidding is a term that is coming into use to designate this operation, especially where certain overhead systems do the work. It consists of assembling the logs at common points for some other method of transportation. This common point in the case of power yarding is at the yarding engine, at a distance ranging from 500 to more than 2,500 feet from the farthestmost tree that is to be yarded at that setting. The yarding engine is set at a drivable stream, railroad, pole road, chute, flume, or "swinging" road, depending on the next step in the transportation of the log. Yarding and the second step in transportation can go on simultaneously when the second step is not driving. Where driving follows yarding, conditions may be such that the second step is delayed.

The above seems to indicate that yarding consists of that transportation accomplished by but one logging engine, which, strictly speaking, is true. The term, however, is applied more broadly to the work done by two or more engines working tandem, provided no costly structure with considerable life, like a pole road, is employed. In that case the long haul over the prepared road is called "roading." The term "yarding" is frequently applied to the whole process—"single," "double," or "triple yarding" being more accurately de-

scriptive terms; or the second and third hauls may be denominated "swinging." The terms are loosely used by the industry, however, so that for clear and accurate discussion, definition of terms is necessary, which in the very nature of the case must be more or less arbitrary.

The term "yarding" in this bulletin is confined to the first haul, which takes the log at the stump. Swinging is considered as transportation that delivers the log from the yarding engine to a pole road, chute, railroad, or drivable stream. One or more engines, of either ground or overhead type, may do the work, but always in connection with very temporary improvements. Roading is considered as the transportation of logs by a logging engine or engines in connection with improvements that are to some extent permanent in character, such improvements consisting of pole roads, chutes, overhead cables, etc.

YARDING.

METHODS.

Power yarding is done in three ways: First, with the log dragging on the ground and the haul-in or main yarding line leading along the surface of the ground from the yarding engine to the log; second, with the log dragging on the ground and the main yarding line leading from the yarding engine to a large lead block suspended near the top of a spar tree standing close by and thence out to the log; third, with the log riding suspended, or partly suspended, from an overhead cable. The first system is known as ground yarding; the second, as high-lead yarding; and the third, as overhead yarding. In addition to these three yarding systems, there are a great number of methods and a great variety of labor, equipment, and supplies used in yarding; more than in any other step in the logging operation.

FACTORS INFLUENCING THE OUTPUT.

Yarding output, the chief element determining cost, is of utmost concern to both the operator and the timber appraiser. Influenced as it is by a great variety of factors, it is hard to estimate. Companies that use a bonus system have proved that abundantly, and they possess every advantage in the shape of records and time, aside from the inducement to make an intensive examination of the territory. The appraiser, who must estimate yarding output at wholesale and after a far less thorough examination, is at a great disadvantage. Following are the factors to be considered. No attempt is made to present them in the order of their importance. They are treated in more detail under the specific methods.

(1) *Methods*.—As will be shown later, each of the different methods is adapted to specific sets of conditions. As a practical logging question, however, it is not always clear which method should be employed. For example, one operator may be securing as good results with the ground method as another operator is securing with the high-lead or overhead method, under practically the same conditions. In some cases, the use of the best method may be out of the question because a machine adapted for it is not at hand, and the amount of timber to be moved does not justify the purchase of new equipment.

(2) *Yarding direction as it relates to the slope of the ground*.—With any method the yarding output is largest on level ground, or on ground sloping moderately toward the yarding engine. The drawback to yarding logs downhill with a ground method is that as soon as gravity carries the log forward faster than the haul-in or main line is traveling, the tendency is for the log or logs to run out of their chokers or to run behind stumps or debris on the side opposite to that on which the line is leading. As a general thing the output with a ground method is from 30 to 50 per cent higher when the logs are moved uphill than when they are moved downhill; assuming, of course, that the ground in question is steep enough in places to cause the logs to run when being yarded downhill, and that the equipment is powerful enough to handle the logs uphill with dispatch. Overhead yarding methods, taking them straight through, work better downhill than uphill. In fact, this method is especially adapted for yarding logs down long, steep slopes.

(3) *Size of timber*.—With the same conditions and within certain limits, the yarding output is less and the load that can be yarded at one trip is less in small timber than in large. A certain amount of time is consumed in making a yarding trip regardless of the number of logs or the volume of timber hauled, since in any event approximately the same amount of time is lost in hooking up, starting, unhooking, and returning the trip line to the woods. Logs of large diameter, assuming that the motive power is ample, are less likely to hang up than small ones. In ground yarding there is special advantage in large timber because it is ordinarily not practical to handle as many logs at a trip as with the overhead, or even with the high-lead method. Under certain conditions, particularly with the overhead and high-lead methods, the effect of small timber on the output may be to some extent offset by cutting long logs. Of course, with fast machinery and relatively larger crews, the yarding output in small timber can be made to approach that in large.

(4) *Yarding distance*.—The general principle is clear and indubitable that the longer the distance over which timber must be conveyed, the less will be the output. It is not directly in propor-

tion to the distance, however, as a large part of the time is consumed in hooking, starting, unhooking, and the like, which is the same whatever the distance.

The economic range, of course, varies with the style of yarding. The high lead affords its peculiar advantages only when confined to a distance of from 500 to 700 feet; ground yarding is generally worked on a maximum of from 600 to 900 feet; while the overhead systems are worked to best advantage on longer reaches, say from 900 to 1,500 feet. Of course, it is sometimes necessary and advisable to use these systems, particularly the latter, at greater distances.

The less of the total burden of transportation assigned to the railroad, the more comes on the yarding, increasing the distance and lowering the output. So the topography of the country has a great deal to do with fixing the yarding distance. While it is possible to build railroads nearly everywhere, it is not always practical to do so because of the high cost of grading and maintaining the track, the large investment, and the danger and high cost of operating trains on heavy grades. The volume of the stand affects the yarding distance in much the same way, as more miles of spur railroad can economically be built where the stand is heavy than where it is light.

(5) *Size of crew.*—Up to a certain point the output increases as the size of the crew is increased. On the other hand, a relatively large output due to a large crew is not necessarily the most economical. Too much can be made of this factor, since, with any system of yarding, the bulk of the crew is largely fixed. For example, in the case of ground yarding, the crew, as a rule, consists of 11 men. This type of crew is more or less elastic in its makeup, however, as ground yarding crews consisting of as many as 14 are used; others contain as few as nine men.

(6) *Condition and care of equipment.*—The output varies with the condition of the equipment, the way it is used, and the length of life expected of it. It is larger when up-to-date machines of the proper size rather than old machines of the wrong size are used, when machines are driven at practically their maximum speed instead of slowly for the purpose of prolonging their life and reducing the cost of maintaining them, and when lines, rigging, etc., are replaced as soon as the signs of wear indicate that they may break, instead of waiting for them to break a number of times before being replaced. There must, of course, be a nice balance between the output and the labor, equipment—maintenance and depreciation—and supply costs per thousand feet. Most operators, no doubt, get as close to this balance as is possible. There are some, however, who could reduce the total cost per thousand feet for yarding by taking better care of the equipment; others who could reduce the cost by speeding up the

engines, if possible, or by securing engines that would stand harder work.

(7) *Loss of time.*—There is of necessity considerable lost time in yarding. Yarding engines have to be moved from one landing to another and from one end of a given landing to the other. Lines have to be run out, and, as the work progresses, changed from one yarding trail to another. These and other delays are necessary. Loss of time results from other causes, such as the inability of the loading department, or the next step in transportation, to handle the yarding output at all times. The aim of camp foremen is to reduce to the minimum the loss of time because of necessary delays and to eliminate unnecessary delays entirely.

A few operators in their endeavor to take care of this factor properly keep a record of lost time. The following is a summary of one of these records for three donkey engines, based on a logging period of six months:

Record of lost time in yarding.

Waiting for trucks, 40 hours	days	4
Moving yarders, 240 hours	do	24
Changing ends, 90 hours	do	9
Total loss, 370 hours		37
Total number of landings		27
Average time lost in moving a yarder from one landing to another	hours	8.9
Average time lost in changing ends	do	3 $\frac{3}{4}$
Average amount of timber yarded to a landing	feet	830,000
Number of yarding days		383
Number of productive yarding days		346

(8) *Amount of defect in timber.*—The yarding output is affected in much the same way by rot as by the size of the timber. It takes as much time to yard a rotten log as a sound one of the same size, and yet the rotten log may not scale more than half as much as the sound one. Much yarding time is lost in disentangling the logs that should be utilized from those that are worthless. The operator has to fell and buck the defective timber—sometimes half the stand—to make sure that no merchantable timber is left. Few factors, either as related to the cost of yarding or the operation as a whole, are so important or so often overlooked as this one.

(9) *Surface of the ground.*—The output with the ground-yarding method is less where the ground is broken up with "potholes," hummocks, small ravines, and the like, than where the ground is relatively smooth. The effect of this factor on the output with the high-lead and overhead methods is not so apparent, particularly with the overhead method.

GROUND YARDING.

Up to within the last year or so the bulk of the timber was yarded by the ground system. Available information does not indicate how much is handled by this system at present. That it has been replaced

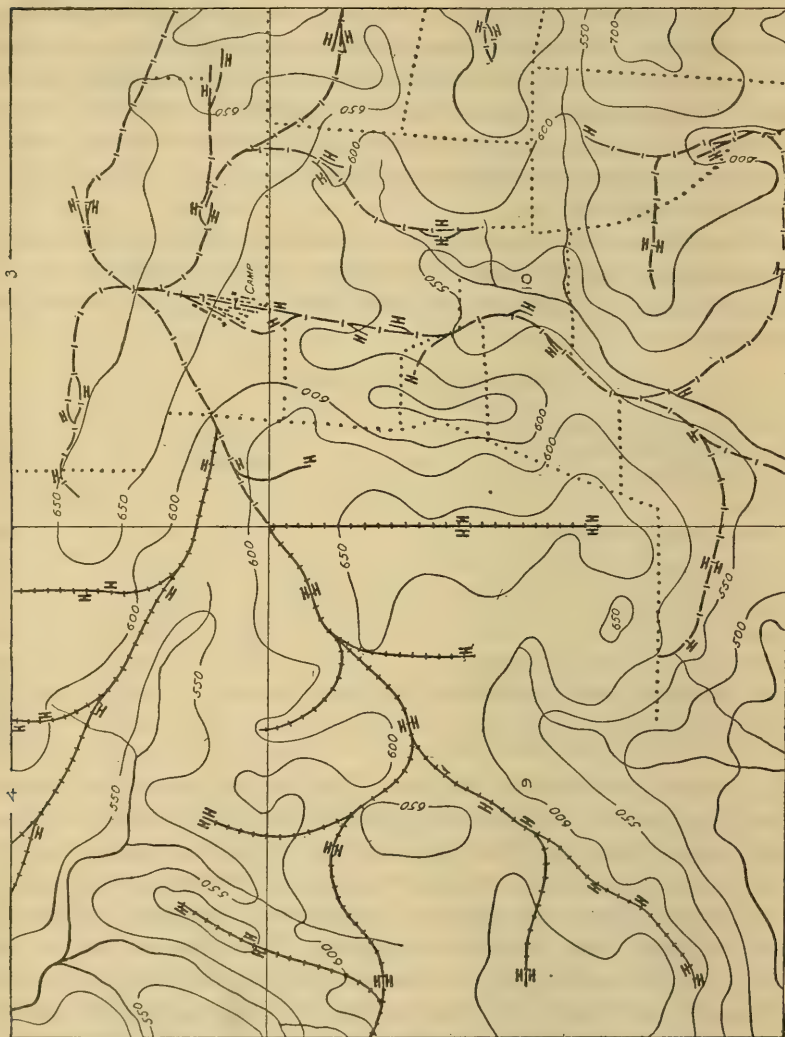
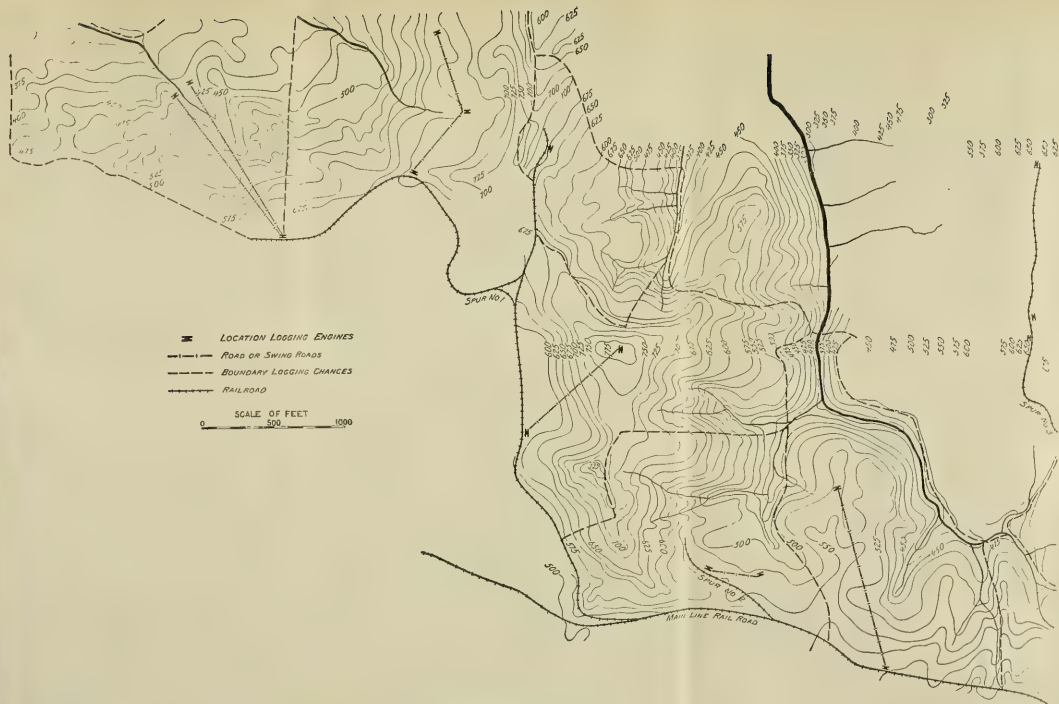


FIG. 16.—Yarding chance in exceptionally good ground.

to a considerable extent by the high-lead and overhead systems is clear. This system of yarding was long the one standard system, and it is the system which present-day operators know best. For this reason it is here treated at greater length than the other systems; indeed, the discussion of ground yarding is made to serve as a basis for the discussion of high-lead and overhead systems.



SHAPE AND SIZE OF YARDING CHANCE.

The shape of yarding chances, or the timber yarded to one point by one yarding engine, depends on the topography of the land. If the land is practically level, making it possible to gridiron the tract with railroads rather regularly laid out, the yarding chances are rectangular in shape, with the side bordering on the railroad about twice the length of the ends. This results in a square tract being yarded to each end of the landing. Seldom, however, does the topography permit the blocking of yarding chances in this manner. As a rule they are very irregular in shape, being bounded by divides, gulches, or the range of practical yarding distance. Figure 16 shows the shape of yarding chances in exceptionally good ground, while figure 17 illustrates the usual irregularity. The chances in the latter case are larger than ordinary.

YARDING DISTANCE.

It is not practical in the abstract to say anything that will indicate the economical maximum yarding distance. Judging from the practice, the distance with the ground-yarding method ranges, under favorable conditions, between 600 and 900 feet, being generally about 800 feet. If conditions are particularly favorable from the standpoint of the volume of the stand and the cost of railroad construction and operation, the distance may be reduced to 500 feet. Too often, as has been pointed out, the topography of the country, by fixing the railroad location, fixes the distance that the timber must be transported by logging engines. In a given case it may be too long to constitute an economical yarding distance and not long enough to justify double hauling. It is then good practice to yard a distance greater than 900 feet.

An important factor influencing the yarding distance, from the standpoint of both railroad and yarding costs, is the average stand of timber per acre. The following distances have been recommended as a general basis of calculation:

- (1) Twenty to forty thousand feet of timber per acre, 1,200 feet maximum yarding distance.
- (2) Forty to sixty thousand feet of timber per acre, 1,100 feet maximum yarding distance.
- (3) Sixty to eighty thousand feet of timber per acre, 1,000 feet maximum yarding distance.
- (4) Eighty to one hundred thousand feet of timber per acre, 900 feet maximum yarding distance.

LOCATION OF YARDING ENGINE SETTING.

The location of the landing or yarding engine setting may be determined by the hook tender, the camp foreman, or jointly by the camp foreman and superintendent. In certain cases the hook tender may shift the settings made by the foreman or superintendent. Where this is permitted, the hook tender is held responsible for any reduction in the output because of an improper setting. In many cases the settings are selected by either the superintendent or foreman, the exigencies of the situation making a conference impractical. Where possible, the superintendent and foreman together should make the selections.

There are logging superintendents and foremen who feel that their success in securing large yarding outputs is largely due to the fact that they exercise the utmost care in blocking out yarding chances and locating settings. When ground conditions permit, the best settings are selected and the railroad is then located in relation to them, instead of the railroad being located first and the chance taken that satisfactory settings can be found along it. In other words, what should be the best railroad location from the standpoint of cheapness of construction and operation would not necessarily be the best location from the standpoint of the total cost of the combined yarding and railroad hauls. Cases can be found where the cost of a piece of spur railroad was excessive because of a location of this kind, the more expensive location being made seemingly for the purpose of securing the best yarding setting, which in turn enabled the yarding crew to get at least the standard output expected of them. Of course, aside from this, any additional output resulting from special railroad construction had the effect of decreasing the cost per thousand feet of succeeding steps in the logging operation.

Where logs are yarded direct to a railroad, the settings, in addition to being where the largest average yarding output can be secured, should be where the logs can be loaded to the cars with dispatch.

MOVING GROUND YARDING ENGINES.

The time lost in moving engines reduces the actual yarding time, and any saving in time in making the engine moves has the effect of increasing the yarding output. It generally takes from 5 to 10 hours to move a logging engine from one setting to another, depending for the most part on whether it is transported on a flat car or dragged over the ground. In one camp the average time, when based on an operating period of six months, amounted to nine hours. The work included moving the engines, raising gin poles for load-

ing purposes, and setting lines. A yarding crew in a camp along the Columbia River loaded the engine on a flat car, moved to a new landing, set the lines, and yarded 54 logs in one day. A hook tender in a camp on the west slope of the Cascades moved a yarding engine over the ground a distance of 2,500 feet in 10 hours with a yarding crew of 11 men. Half the move was made up a grade of 40 per cent. The ground was practically clear of chunks of trees.

From two to four hours' time is consumed in moving the engine from one end of the landing to the other. In one camp in Washington where the ground was practically level the average time, when based on a six months' operating period, was three and one-third hours. This included running out the lines. A crew in a camp along the Columbia River changed ends and ran the trip line around a week's yarding in 2 hours and 10 minutes. The ground conditions were favorable. Another crew in the same region changed ends and ran the trip line out in 1 hour and 25 minutes. The ground was exceptionally good. Another hook tender in the same region changed ends and yarded 78,000 feet in a day, two and one-half hours being consumed in changing ends.

The actual cost of moving engines is not so large where the work is performed by the crew that clears the right of way and constructs landings, or by a special crew. With the ability to move logging engines as one of the qualifications of the hook tender in charge of the logging engine moving crew, the move is made more quickly. The daily cost of this crew is not so large as that of a regular yarding crew.

One method of reducing the loss of time is the use of an extra yarding engine and, if the motive power for loading is furnished by a separate engine, an extra loading engine, so that all a crew has to do when it has completed the yarding of the timber tributary to a landing is to move the small equipment to the new landing where the extra equipment has been put in place. The move by this method should take about 30 minutes. At a convenient time the crew that is engaged in clearing rights of way and building landings, or a small special crew, moves the extra equipment to the new landing and runs out the lines. The hook tender, who is to yard the timber, may supervise the work of placing the lines. Just before the move is made the fireman of the yarding crew goes ahead to raise steam in the extra machines and have everything in readiness so that yarding can proceed as soon as the rest of the yarding crew arrive.

There are other reasons than the increased yarding output for using extra equipment. The daily cost of the operations following yarding is to a great extent fixed. When a yarding crew is moving from one side to another the output from the camp is curtailed. The longer it takes to make the move the greater the curtailment. This

curtailment has the effect of increasing the unit cost of succeeding steps in the operation. In the case of a two-side camp the output is cut in two during the time the move is being made, so that the unit cost of succeeding steps is practically doubled. Extra yarding equipment also gives the man who looks after the machinery an opportunity to examine the idle machinery and see that everything is in good running condition, thus adding to the safety of the operation and reducing to a minimum the chance of tying up a yarding crew because of a breakdown, or, if breakdowns occur, the crew can change to a machine already set so as to lose no time in waiting for repairs to be made.

The practice of using an extra yarder in the above-mentioned manner is not common, and no operator running less than three sides would consider it desirable.

SETTING THE LINES.

With the boundaries of the yarding chance known and the yarding engine placed in position at one end of the landing, the yarding crew sets about running out the main and return lines. The first step is to locate the first yarding road. If all the timber on the chance is felled, and it usually is, the usual practice is to locate the first road, which is really not a road but the route the logs will follow to the landing, on the side bordering the railroad, succeeding roads following each other right around the chance. These roads radiate in a half circle from the center to the border of the chance. Since the roads lead directly to the landing, it is not necessary to locate them in advance, except in a general way. Figure 18 shows the location of the yarding roads.

After the first road is located the straw line is dragged by hand over the road from the yarding engine and passed through a block, which is adjusted to a tail tree at the far end of the road. From there it is taken 300 feet or more to the right or left, depending on the direction the chance is being worked, along the back boundary of the chance and through another block, and then on to the yarder. At the yarding engine, the end of the straw line which has just been dragged in is attached to the trip line and the other end is reeled in on the small drum. This drags the trip line out to and through the blocks and back over the road to the yarder. The straw line is then detached and the end of the main line attached to the trip line by means of a clevis. The yarder is now ready for operation.

In changing from one road to another the method in general is the same. Before the crew gets ready to change to a new road the hook tender may, with the aid of one of the choker setters and the sniper, run out the straw line on the new road and hang the extra head block.

Then, as soon as the last log is on the old road, the chaser unhooks the trip line from the main line and sends it back. When it reaches the new tail tree the hook tender is there to attach it to the straw line and send it in over the new road to the yarder, where it is attached to the main line. By the time the crew has moved up to the front of the new road the butt chain has arrived, thus enabling them to start hauling logs again with practically no loss of time.

Until quite recently the trip line was run out and changed from one road to another by hand, and in some camps this method is still

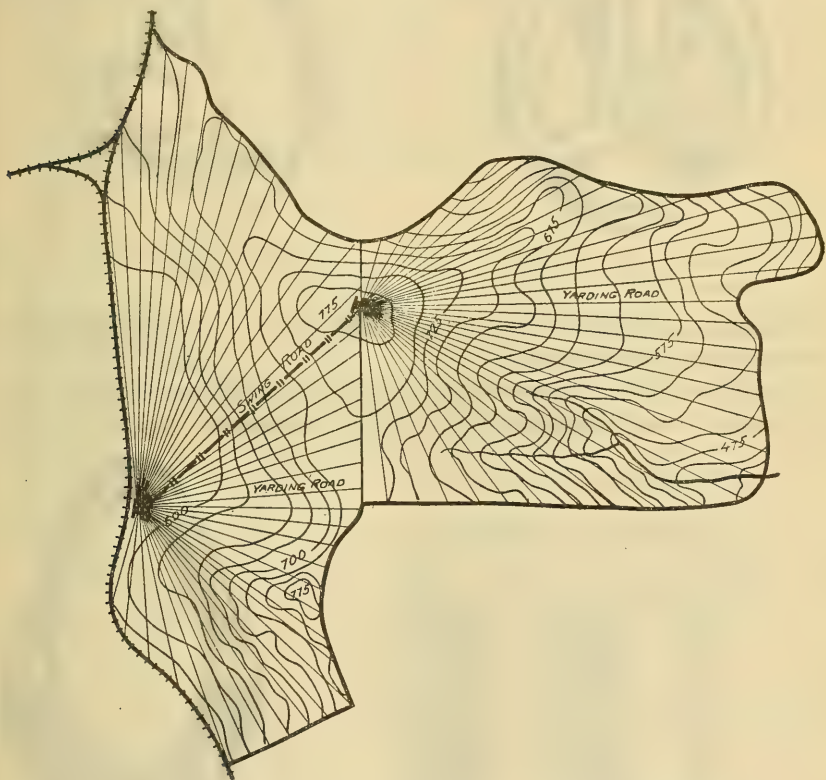


FIG. 18.—Logging chance showing location of ground yarding roads.

used because of the character of the yarding engines. All operators that have used a straw line, which should consist of $\frac{3}{8}$ -inch plow-steel cable, are convinced that it is a valuable piece of equipment, especially in rough, steep ground. It has been estimated that it increases the yarding output from 10 to 15 per cent.

In addition to the two head trip blocks (fig. 19), which are hung to the tail trees by means of straps made from short pieces of cable, it may be necessary to reduce wear and tear on the trip line, to use two or three other trip-line side blocks (fig. 20), either between the

tail trees or between the second tail tree and the yarder. The placing of the trip line several rods distant from that being logged obviates

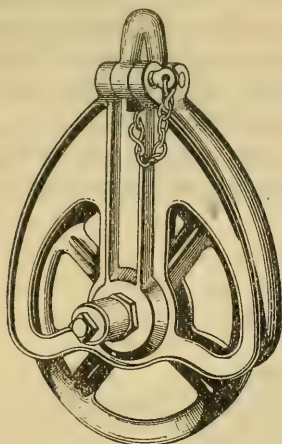


FIG. 19.—Trip line head block.

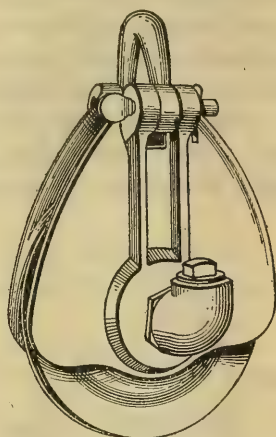


FIG. 20.—Trip line side block.

frequent change in its position and also keeps it out of the way of the logs as they are hauled in.

The set-up described above has the main line leading straight from the main drum, through the main-line fairleader (fig. 21), across

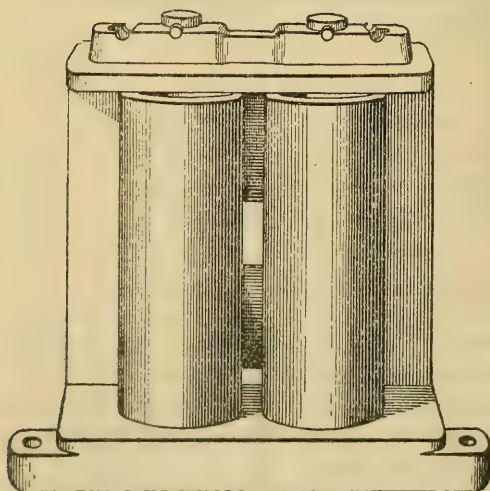


FIG. 21.—Main-line fairleader.

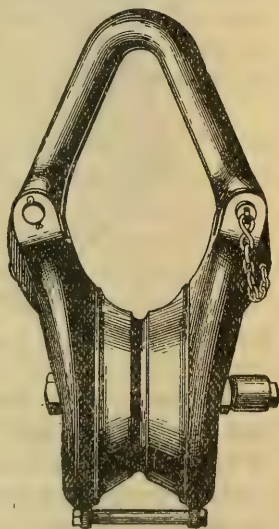


FIG. 22.—Butt chain lead block.

the landing, and out along the road to the timber. Only a small percentage of the timber can be yarded with the lines leading in this way. Most of the roads will form an angle with an imaginary line

run from the main-line drum across the middle of the landing, some of the angles formed being a little larger than a right angle. This difficulty is generally overcome by leading the main line through a butt-chain block (fig. 22) hung to a stump standing in line with the yarder and landing and 50 feet or more from the approach end of the landing. In operation the log is yarded to the butt-chain block, the chokers are all unhooked from

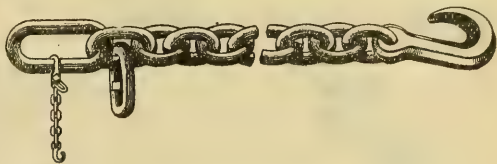


FIG. 23.—Butt chain.

the butt chain, permitting the butt chain to be passed through the block. The chokers are again hooked to the butt chain and the log continues on its way to the landing.

OPERATION.

After the ground around the landing has been freed of large chunks of waste material, the butt chain (fig. 23) attached to the main line is run out to the first log on the new road. The choker men put the chokers (figs. 24 and 25) around the end of the logs. After the load has been connected to the butt chain, the hook tender or head-rigging slinger signals for the engineer to haul in on the cable and the load starts down the road. When it reaches the butt-chain block, as it will in most cases, the chaser signals

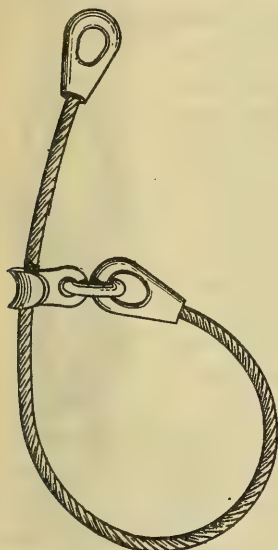


FIG. 24.—Choker with socket.

for the engine to stop, unhooks the chokers from the butt chain, pulls the butt chain through the butt-chain block, rehooks the chokers to the butt chain, and signals for the engineer to go ahead. The load is then dragged to the landing, where it is disconnected by the chaser, or in rare cases, by one of the loaders.

Where the logs are large, only one is hauled at a trip. In other cases it may be practical to yard as many as six. In general, the number depends on the volume of the logs, the size of the equipment, and the ground conditions.

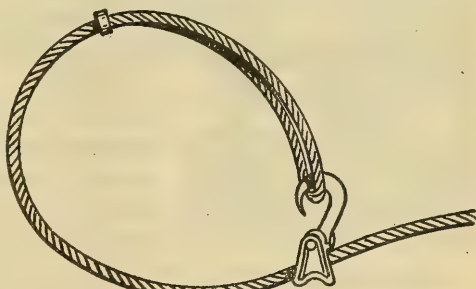


FIG. 25.—Choker with eye.

As a rule, one choker is used with each log. One, two, and occasionally three, chokers are attached to a butt chain. Where

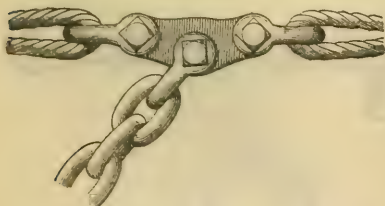


FIG. 26.—Rigging plate.

more than one butt chain is required, a rigging plate (fig. 26), to which a second butt chain is attached, is inserted in the main line about 50 or 60 feet from the end of the main line or the point to which the usual butt chain is attached, the distance de-

pending on the length of the longest logs hauled.

Occasionally, it is necessary to use a yarding block (fig. 27) to side line the logs around stumps or other obstructions, or to pull them backwards until they are clear. In the case of exceptionally large logs it is sometimes necessary to increase the power of the yarding engine by the use of a yarding block. When this is done, the end of the main line is attached to a tree along the road at some distance from the log in the direction of the yarding engine, a yarding block is hung in the bight of the line, and the shackle of the block is attached to the log. After the log has been moved up to the point where the line is attached to a tree, a new "tail-hold" is taken on another tree nearer the yarder.



FIG. 27.—Yarding block.

The butt chain lead block, or bull block, has been replaced to some extent by yarding or stump rollers (fig. 28). This device allows the same speed with less friction, and does away with the services of one man. By placing three rollers on the arc of a circle, it is possible and practical to log directly back of the landing without the use of a lead block. It has been estimated by an operator that the use of these rollers instead of lead blocks increases the output of a yarding crew between 9 and 10 logs per day, not taking into account the fact that the crew is reduced by one man. Of course, there are many chances where the use of a stump roller would not be practical.

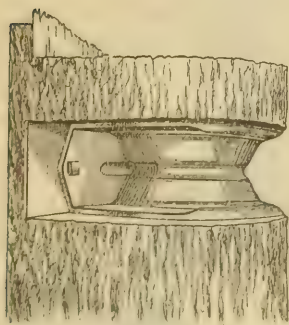


FIG. 28.—Yarding or stump roller.

ORGANIZATION OF CREW.

The number of men in a ground-yarding crew varies by camps and in the same camp by chances. The usual crew consists of the following men:

1 hook tender.	1 chaser.
1 swamper.	1 signal man.
1 sniper.	1 engineer.
2 rigging slingers.	1 fireman.
2 choker men.	1 wood buck.

In some cases only one rigging slinger is used. Where the haul is long and the ground particularly rough, an additional choker man may be necessary. Sometimes two wood bucks are required. If oil

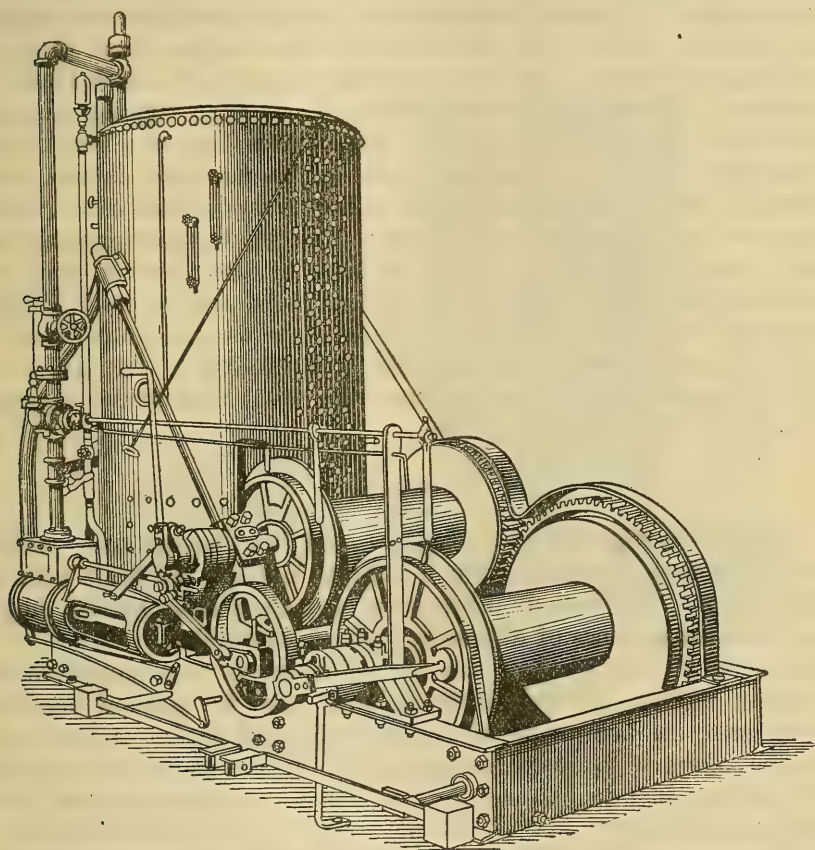


FIG. 29.—Combination road and yarding engine.

is used as a fuel, a wood buck and, in some cases, a fireman are not needed.

The division of labor in a yarding crew is not always clear. The different members of the crew do what the situation demands. The hook tender is in charge of the crew, and the amount of work done depends largely on his ability. He plans the work, locates the roads, instructs the crew as to the character of the timber that should be hauled, designates the order in which the logs are to be taken, and

assists the rigging slingers with their work. The swamper works just ahead of the rigging men, knots the logs, fells small timber that may be a source of danger to the crew, chops out the brush, and improves the roads, so that the logs can be brought out without being hung up. When necessary, the sniper rounds off the under side of the front end of the logs, so that they will slide over obstructions. In rough country, where the logs are apt to roll and to be dragged first on one side and then on the other, they are usually sniped all the way around. The depth of the snipe depends partly on the size of the log and partly on the ground conditions, ranging from little or nothing to 9 inches. The head rigging slinger is the hook tender's assistant. Working alone or assisted by another rigging slinger, sometimes two others, he unhooks the chokers from the butt chain when the main line is returned, hooks up the new load of logs, and starts it toward the landing. The principal duty of the choker men is to put the chokers around the logs. The chaser, standing near the butt chain block, signals to the engineer in case there is need for stopping the engine. His principal work is to pass the load of logs by the butt-chain block. The signal man, by means of signals, usually given by pulling on a wire attached to the whistle of the yarder or by an electrical device, transmits the order of the hook tender, rigging slinger, or chaser to the engineer.

EQUIPMENT.

Ground logging engines.—Engines used in swinging and roading on the ground, as well as ground yarding engines, are dealt with in this section. While their inclusion here is not exactly logical, clearness and convenience of discussion make it advisable.

Figures 29 and 30 show the compound-gearred and tandem-drum logging engines, the two standard types used for ground logging. As a rule, the narrow-drum, compound-gearred engine is used, the compounding of the gears having proved the best method of securing the proper relation between the two drums in regard to speed and pulling power.

The wide-drum, simple-gearred engine is also used, but principally for swinging and roading, where high speed in the lines and large drum capacity are of major importance. Wide-drum engines bear special trade names, depending on whether they are adapted for yarding and swinging or roading, the chief differences lying in the drum proportions and friction devices. The engines and boilers of a long-haul road engine are, of course, larger than those of an engine adapted to haul at relatively shorter distances.

Probably no other class of machinery is called upon for such extremely severe service as logging engines. The demands made upon

them are frequently far beyond their normal capacity. To see them hauling logs larger than 10 feet in diameter and 24 feet in length over rough ground on a "straight" line is to marvel that they are not wrecked in a short time. That they are not is due to the fact that they are simply, compactly, and powerfully built of the best adapted material. The frame or bed of the machine, on which the security of all fastenings and the permanency of alignments of all working parts depend, is strong and rigid, being made of the heaviest standard section of steel beams spaced by heavy crossbars of cast iron or steel.

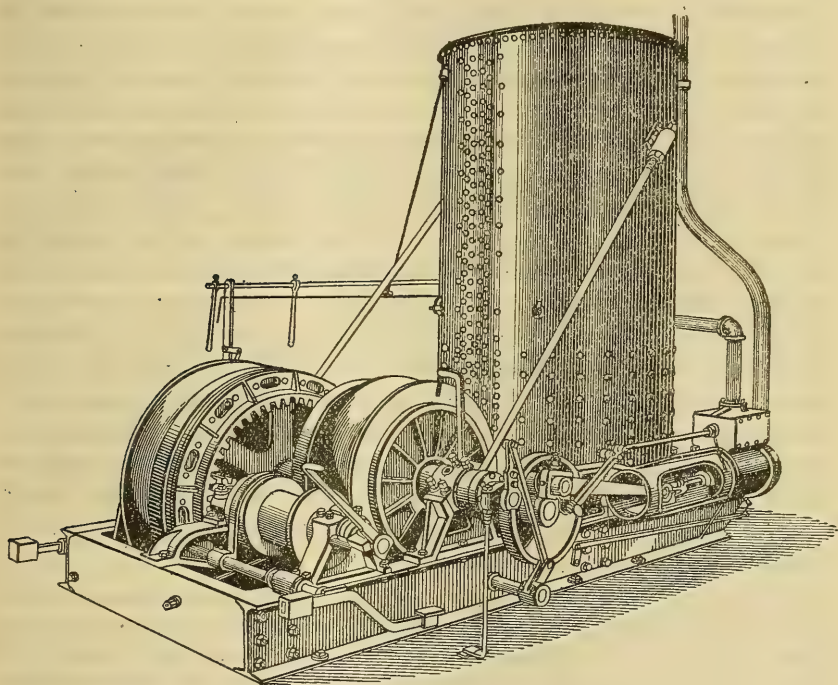


FIG. 30.—Compound-g geared yarding engine.

Logging engines are equipped with high-pressure boilers of the vertical type, built of 60,000-pound flange steel. They have a working pressure of from 150 to 200 pounds (generally 200 pounds), and are guaranteed to pass Hartford inspection. They range in size from 48 inches in diameter and 96 inches in height to 80 inches in diameter and 153 inches in height.

The extreme height and high working pressure of these boilers, the limits of which have been reached, is the result of constant increase in the cylinder sizes. The width of the engine frame, by limiting the diameter of the boiler, has restricted the dimensions of the round fire box, resulting in too small a proportion of grate to heating surface. To overcome the steaming difficulties resulting from insuffi-

cient grate area, most new logging engines are equipped with a fire box which is oblong or elliptical in shape and extends about 2 feet beyond the cylindrical portion of the boiler on the front side. This design increases the grate area considerably without correspondingly increasing the width of the engine frame.

All of the engines are double—that is, have two cylinders. Ordinarily, logging engines are classified by the size of the cylinders, the diameter being given first. A glance at Table 7 shows the range of sizes. The engines are of the heavy-duty type, the valves and valve gear differing with the make.

Standard drum engines have two drums, placed either tandem or opposite, or nearly so. These rotate upon their shafts and are held fast when pulling by means of frictions. Several types of frictions are used. They are operated either by hand or steam, the steam friction being particularly desirable on the larger engines. The main, or hauling, drum is made of steel; the trip drum, which carries the trip, or return line, is made of semisteel. These engines can be equipped with loading and straw-line drums, driven either by their own gear or pinions or by a chain drive. In the case of the simple-geared engine, the cut-steel gears of the main and trip drums are driven by a cut-steel pinion on the engine crank shaft. The trip drum of the compound-geared engine is driven in a similar way. The main drum in the latter type, however, is driven through a compound train of gears by an internal or external gear, a second pinion keyed on the trip-drum shaft driving the gear of the main-drum shaft.

The standardization committee on logging engines of the Pacific Logging Congress recommended that the following definitions and formulas be adopted as standard:

(a) *Right and left hand sides of a logging engine.*—When standing at the boiler end of the engine and facing out over the drum, that side of the machine to the right is termed the right-hand side and that to the left is termed the left-hand side. In general, the engine is operated from the right-hand side. This is frequently called the “engineer’s side.”

(b) *Main and trip drums.*—The main drum is the drum which is used to haul in the load. This is sometimes called the forward or the lower drum. The drum which is used to return the main hauling line is the trip drum, also called the haul-back drum.

(c) *Rope capacity.*—The rope capacity of the main drum and trip drum must bear a more or less definite relation. On road engines the trip-drum capacity should be not less than twice the capacity of the main drum, and so far as practicable there should be approximately six or seven hundred feet of additional capacity on the trip drum. On yarding engines the capacity of the trip drum should be at least two and one-fourth times that of the main drum, and so far as practicable this ratio should be slightly increased. To find the drum capacity the following formula is used:

$$\text{Capacity} = C \times L \times \frac{D+d}{2} \times \frac{D-d}{2}.$$

D equals diameter of flange, in inches.

d equals diameter of barrel, in inches.

L equals length between the flanges, in inches.

C equals constant, varying for each size of line.

Value of C.

Size of line.	Constant.	Size of line.	Constant.
$\frac{1}{8}$ inch.....	4.16	1 inch.....	0.262
$\frac{3}{8}$ inch.....	2.67	1 $\frac{1}{8}$ inches.....	.207
$\frac{1}{2}$ inch.....	1.86	1 $\frac{1}{4}$ inches.....	.167
$\frac{5}{8}$ inch.....	1.37	1 $\frac{3}{8}$ inches.....	.138
$\frac{3}{4}$ inch.....	1.05	1 $\frac{1}{2}$ inches.....	.116
$\frac{7}{8}$ inch.....	.828	1 $\frac{3}{4}$ inches.....	.099
1 inch.....	.672	1 $\frac{7}{8}$ inches.....	.085
1 $\frac{1}{8}$ inch.....	.465	1 $\frac{1}{2}$ inches.....	.074
1 $\frac{1}{4}$ inch.....	.342	2 inches.....	.066

Using the above formula, the drum capacity is obtained by multiplying the sum of one-half the diameter of the flanges and one-half the diameter of the barrel by the difference between one-half of the diameter of the flanges and one-half the diameter of the barrel by the length between the flanges and the constant for the size of the line required. Five-eighths inch line is almost universally used for trip lines. The main line varies from 1 inch to 1 $\frac{3}{8}$ inches in diameter.

In computing the proportion between the main drum and the trip-drum rope capacities it is assumed that the main line is 1 $\frac{1}{4}$ inches and the trip line $\frac{5}{8}$ inch.

(d) As a matter of relative comparison only, the speed of any line is the speed of the line when the drum is one-half full of cable and engine is running at a piston speed of 600 feet per minute.

(e) *Standard logging engine.*—What is known as a standard logging engine is a two-drum machine complete with boiler, hood, stack, spark arrester, and one gypsy head. Patented spark arresters, straw-line and loading drums, and the like, are additional equipment, and usually are furnished at extra cost. In the case of narrow drum yarders where a true lead is necessary on the drums, one main line and one trip line fair-leader should be furnished with each engine.

(f) *Boilers.*—The working pressure of boilers 48 inches or larger in diameter should not be less than 175 pounds. Boilers are rated by their inside diameters and the over-all length of effective shell. Any extension below the water leg for the ash pan or any extension above the tube sheet for the breeching is not considered part of the effective shell.

(g) *Pulling power.*—The pulling power of any drum can be obtained by the following formula:

$$W = \frac{r \times G \times P \times A}{R}$$

W=Weight or pull on cable.

P=Full boiler pressure.

A=Area of one cylinder.

r=Radius of crank.

R=Radius of drum.

G=Gear ratio drum.

The size of yarding engines varies in different camps. An operator who has given more than the usual amount of attention to this question, and who has a reputation for consistently securing large yarding outputs, made the following recommendations, based on uphill yarding:

(a) A 10 by 11 inch compound-gearred, high-speed yarding engine of any standard make to be used in yarding timber on practically flat ground where the yarding distance does not exceed 1,000 feet, the difference in elevation over the yarding area does not exceed 75 feet, and the volume of the largest logs does not exceed 1,000 feet.

(b) An 11 by 13 inch compound-gearred, high-speed yarding engine of any standard make to be used in yarding timber on rolling ground where the yarding distance does not exceed 1,000 feet, the difference in elevation over the yarding area does not exceed 150 feet, and the volume of the largest logs does not exceed 5,000 feet.

(c) A 12 by 14 inch compound-gearred yarding engine of any standard make to be used where conditions are more severe than those stated above.

(d) The engines to be equipped with high-pressure boilers of large capacity and three drums.

The following gives the sizes of engines used in several camps:

(a) Compound-gearred 11 by 13 inch yarding engines are used. They are new, and equipped with the extended fire box. The logging superintendent is considered one of the most efficient on the coast. The country is mountainous, rough, and badly broken up. The slopes in general are steep. Logs were moved both uphill and downhill; uphill when possible. They averaged about 2,000 feet in volume, and logs containing from 7,000 to 8,000 feet were not uncommon.

(b) Compound-gearred 10 by 11 inch yarding engines were used. They were new, and had extended fire boxes. The ground was quite flat, regular, and relatively free of brush and down timber. The logs averaged about 600 feet in volume. Never less than two, sometimes three, and occasionally four logs were yarded at a trip.

(c) Compound-gearred $10\frac{1}{2}$ by $10\frac{1}{4}$ inch yarding engines were used. The timber was second growth, dense, and of fair height, averaging about 30 inches D. B. H. The logs averaged about 600 feet in volume. The ground was practically level and quite free of ravines, pot holes, brush, and down timber.

(d) Compound-gearred 12 by 12 inch yarding engines were used. The country was mountainous and badly broken up, being considered a hard chance. The logs, including cedar slabs, averaged 1,200 feet in volume, but logs ranging from 5,000 to 7,000 feet in volume were not uncommon.

(e) Small engines are being replaced by high-speed, 11 by 13 inch compound-gearred engines. The country is rough, the logs averaging 1,000 feet in volume. Some of the logs scale 5,000 feet.

The prices of logging engines are given in the following tables. They are those of March, 1916. The prices given do not include fair-leaders, loading or straw-line drums, the extended fire box, or other special devices.

TABLE 8.—*Prices of compound-gearred yarding engines.*

Size of engines.	Capacity of drums.	Size of boilers (circular).	Speed of lines.	Weight.	Net price f. o. b. Portland, Tacoma, and Seattle.
<i>Inches.</i>	<i>Feet.</i>	<i>Size of line, inches.</i>	<i>Inches.</i>	<i>Feet per minute.</i>	<i>Pounds.</i>
10 by 10½.....	(Main, 1,470.. Trip, 3,375..)	1½ 8000	62 by 132 high.....	(Main, 270.. Trip, 1,100..)	34,500
10 by 11.....	(Main, 1,700.. Trip, 3,700.. Straw, 3,700..)	1½ 8000	66 by 125 high.....	(Main, 265.. Trip, 790....)	33,500
10 by 12.....	(Main, 950.. Trip, 2,460..)	1½ 8000	54 by 125 high.....	(Main, 260.. Trip, 575....)	29,000
11 by 12.....	(Main, 1,400.. Trip, 3,500.. Straw, 3,375..)	1½ 8000	68 by 144 high.....	(Main, 320.. Trip, 1,210..)	44,500
11 by 13.....	(Main, 1,500.. Trip, 4,050.. Straw, 4,000..)	1½ 8000	66 by 125 high.....	(Main, 259.. Trip, 695....)	40,000
12 by 12.....	(Main, 1,400.. Trip, 3,500.. Straw, 3,375..)	1½ 8000	68 by 144 high.....	(Main, 320.. Trip, 1,210..)	46,000
12 by 13.....	(Main, 1,500.. Trip, 3,400.. Straw, 3,375..)	1½ 8000	74 by 144 high.....	(Main, 330.. Trip, 1,400..)	53,000
12½ by 12.....	(Main, 1,760.. Trip, 3,900..)	1½ 8000	68 by 147 high.....	(Main, 275.. Trip, 930....)	45,000
12 by 14.....	(Main, 1,840.. Trip, 5,500.. Straw, 5,500..)	1½ 8000	72 by 144½ high.....	(Main, 237.. Trip, 665....)	50,000
12 by 14 (special)...	(Main, 1,900.. Trip, 5,500.. Straw, 5,500..)	1½ 8000	72 by 144½ high.....	(Main, 285.. Trip, 665....)	50,000
12 by 13.....	(Main, 1,500.. Trip, 3,900..)	1½ 8000	68 by 144 high, ex- tended fire box.	(Main, 275.. Trip, 930....)	49,000
13 by 13.....	(Main, 1,500.. Trip, 3,400.. Straw, 3,375..)	1½ 8000	74 by 144 high.....	(Main, 330.. Trip, 1,440..)	54,500
13 by 13.....	(Main, 1,500.. Trip, 3,900..)	1½ 8000	68 by 144 high, ex- tended fire box.	(Main, 275.. Trip, 930....)	51,000

The capacity of the drums in Table 8 is for one size of rope. The following table shows the approximate capacity of the main drums of the engines given in ropes of other sizes that may be used. The order is the same in both tables.

TABLE 9.—*Length of rope for compound-gearing yarding engines.*

Diameter of rope (inches).					Diameter of rope (inches).				
Engine.	1	1½	1¾	1⅞	Engine.	1	1½	1¾	1⅞
Length of rope.					Length of rope.				
<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Inches.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
10½ by 10.....	1,800	1,470	1,270	.....	12 by 13.....	1,840	1,500	1,225	.....
10 by 11.....	2,100	1,700	1,350	.....	12½ by 12.....	1,570	1,250	1,030	.....
10 by 12.....	1,275	1,000	850	.....	12 by 14.....	2,750	2,220	1,840	.....
11 by 12.....	2,200	1,750	1,400	.....	12 by 14 (special) ..	2,370	1,900	1,570	.....
11 by 13.....	.....	1,730	1,500	1,220	12 by 13.....	1,840	1,500	1,225	.....
12 by 12.....	.....	1,770	1,400	1,200	13 by 13.....	1,840	1,500	1,225	.....

TABLE 10.—*Tandem drum logging engines.*

Capacity of drums.			Size of boilers.	Speed of lines.	Weight.	Net price f. o. b. Portland, Tacoma, or Seattle.
Dimensions.	Size of line.					
Inches.	Feet.	Inches.	Inches.	Feet per minute.	Pounds.	
9 by 10.....	Main, 2,250.. Trip, 5,340..	1	48 by 103 high, 175-pound working pressure.	Main, 400.. Trip, 470....	18,000	\$2,200
9 by 10½.....	Main, 2,950.. Trip, 5,800..	1	54 by 106 high.....		19,500	2,000
9½ by 10.....	Main, 2,150.. Trip, 5,340..	1	54 by 125 high, 175-pound working pressure.	Main, 350.. Trip, 470....	20,500	2,360
9½ by 10.....	Main, 2,900.. Trip, 6,500..	1	56 by 124 high, 200-pound working pressure.	Main, 400.. Trip, 500....	26,000	2,725
10 by 11.....	Main, 3,000.. Trip, 6,900..	1	60 by 126 high.....	Main, 422....	28,000	2,800
10 by 12.....	Main, 3,150.. Trip, 7,550..	1	54 by 125 high, 175-pound working pressure.	Main, 357.. Trip, 445....	27,000	3,130
10 by 12.....	Main, 4,000.. Trip, 10,000..	1	66 by 120 high.....	Main, 430.. Trip, 560....	32,000	4,000
10 by 13.....	Main, 4,000.. Trip, 8,200..	1	66 by 125 high.....	Main, 380.. Trip, 513....	34,200	3,420
10 by 15.....	Main, 3,750.. Main, 4,660.. Trip, 10,100..	1	68 by 147 high.....	Main, 400.. Trip, 490....	32,500	3,780
10½ by 12.....	Main, 2,800.. Trip, 7,550..	1	60 by 135 high, 200-pound working pressure.	Main, 377.. Trip, 455....	31,500	3,400
10½ by 12.....	Main, 2,100.. Trip, 3,700..	1	60 by 135 high, 200-pound working pressure.	Main, 390.. Trip, 595....	32,000	3,410
11 by 12.....	Main, 3,700.. Trip, 8,250..	1	62 by 132 high, 200-pound working pressure.	Main, 430.. Trip, 625....	36,500	3,550
11 by 13.....	Main, 4,080.. Main, 5,380.. Trip, 10,600..	1	68 by 147 high, 200-pound working pressure.	Main, 430.. Trip, 500....	40,000	4,410
11 by 13.....	Main, 5,500.. Main, 4,500.. Trip, 8,500..	1	66 by 125 high.....	Main, 395.. Trip, 550....	37,000	3,700
11 by 13.....	Main, 3,100.. Trip, 6,400..	1	68 by 144 high, 200-pound working pressure.	Main, 435.. Trip, 600....	40,000	4,230
11 by 14.....	Main, 5,900.. Trip, 11,300..	1	66 by 120 high.....	Lower, 460.. Trip, 520....	37,000	4,300
12 by 12.....	Main, 3,000.. Trip, 7,000..	1	72 by 120 high.....	Main, 465.. Trip, 825....	40,000	4,500
12 by 12.....	Main, 4,070.. Main, 5,400.. Trip, 9,850..	1	68 by 147 high, 200-pound working pressure.	Main, 445.. Trip, 496....	42,000	4,725
12 by 13.....	Main, 4,070.. Main, 5,400.. Trip, 9,850..	1	68 by 147 high, 200-pound working pressure.	Main, 445.. Trip, 496....	45,000	5,200
13 by 13.....	Main, 6,500.. Trip, 14,400..	1	74 by 144 high, 200-pound working pressure.	Main, 565.. Trip, 735....	50,000	5,250
12 by 14.....	Main, 4,350.. Main, 5,100.. Trip, 13,850..	1	72 by 147 high, 200-pound working pressure.	Main, 452.. Trip, 567....	51,000	5,250
12 by 14.....	Main, 6,900.. Trip, 10,500..	1		Main, 420.. Trip, 530....	50,000	5,000
12 by 14.....	Main, 3,300.. Trip, 7,400..	1	68 by 144 high, 200-pound working pressure.	Main, 558.. Trip, 605....	42,000	4,795
13 by 14.....	Main, 6,500.. Main, 8,000.. Trip, 12,800..	1		Main, 500.. Trip, 550....	43,000	5,000
14 by 14.....	Main, 8,100.. Trip, 21,400..	1			60,000	6,000
14 by 15.....	Main, 8,500.. Trip, 21,500..	1	80 by 153 high, 200-pound working pressure.	Main, 630.. Trip, 885....	65,000	6,500

Logging engine repair parts and materials.—All operators find it desirable to carry in stock a few duplicates of the small parts of logging engines that are most likely to fail. The fixed investment in such parts varies with the ideas of the management and the distance the operation is from points where repair parts can be purchased. For the purpose of a timber appraisal, the capital invested in this way may be placed at \$100 per yarding engine.

Logging engine sleds.—For protection and convenience in moving, logging engines are mounted on well constructed sleds (Fig. 14). The more rigid and well secured such a sled is, the more aid it is in preserving the alignment and durability of parts. Sleds are equipped with heavy rings, chains, bolts, etc., for moving, snubbing, etc. They vary in length, ranging from 30 to 60 feet for both yarding and roading engines.

The total cost of these sleds ranges from \$300 to \$600. One 60-foot sled cost \$600, \$309 of which was expended for labor. It is estimated that 15,000 feet of No. 1 logs and 1 ton of iron were used in its construction. The runners were hewn on three sides. The total cost of building a 42-foot sled amounted to \$293. This sled contained 11,000 feet of No. 1 logs, which were valued at \$114. The labor cost of building three 40-foot sleds amounted to \$612, which is at the rate of \$204 per sled.

The life of sleds varies with the character of the sled and of the country, the way moving is accomplished, and the size of the machine. As a general thing it ranges between three and four years.

Fair-leaders.—In the case of narrow drum yarding engines, where a true lead is necessary on the drums, one main line and one trip line fair-leader are mounted on the front end of the logging engine sled. They are made in a number of different designs. Figure 21 shows a main line fair-leader which is adapted for extra heavy service. It weighs 1,220 pounds and is sold for \$100. Figure 31 shows a trip line fair-leader which is adapted for a $\frac{5}{8}$ -inch line. It weighs 246 pounds and costs \$50. A larger fair-leader of this type may be used for the main line. One adapted for 1-inch or $1\frac{1}{8}$ -inch line weighs 675 pounds and costs \$100.

Spark arresters.—In the States of Oregon and Washington the use of spark arresters under certain conditions is compulsory from June 1 to October 1, the Oregon law, which is substantially the same as that of Washington, reading:

From June 1 to October 1 of each year it shall be unlawful for any person, firm, or corporation, or employee thereof, to use or operate any locomotive, logging engine, portable engine, traction engine, or stationary engine using fuel

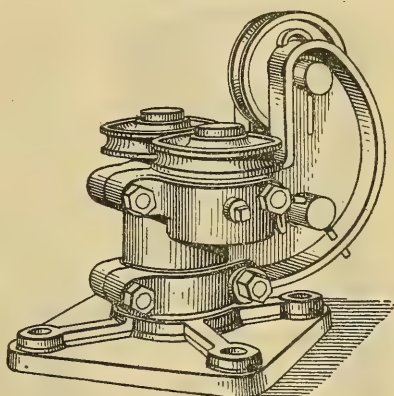


FIG. 31.—Trip line fair-leader.

other than oil, in or near forest or brush land, which is not provided with an adequate spark arrester kept in constant use and repair. Any person, firm, or corporation who shall willfully fail to comply with the foregoing provisions of this section shall be guilty of a misdemeanor, and upon conviction thereof shall pay a fine for each engine or locomotive without such spark arrester of not less than twenty-five dollars (\$25.00) nor more than one hundred dollars (\$100.00), and shall be enjoined from further use of such engine or locomotive until such spark arrester is provided. Escape of fire from an engine shall be prima facie evidence that such appliance has not been adequately maintained in compliance with this section. Under proof that any prosecution has been instituted under this section by any fire warden, any court of competent jurisdiction shall enjoin the further use of the engine involved, unless equipped and maintained in compliance with this section to the satisfaction of said fire warden, until the defendant has been acquitted of the charge preferred.

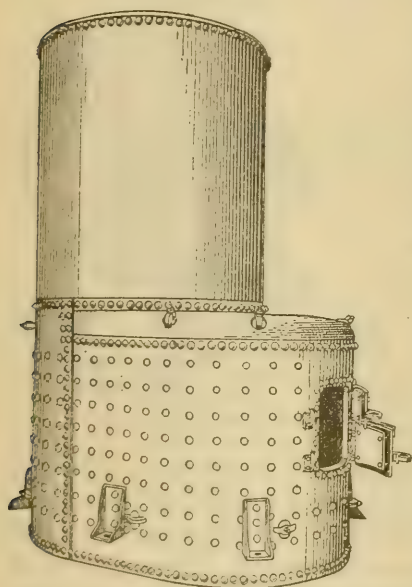


FIG. 32.—Extended fire-box type of boiler.

There are a number of different types of spark arresters used. The prices vary with the type of arrester and the size of the engine stack. What is claimed to be a particularly effective arrester can be purchased for from \$125 to \$160. Prices in general range from \$20 to \$160.

Extended fire boxes.—Manufacturers of logging engines are prepared to equip all logging engines having cylinders 10 inches or larger in diameter with extended fire boxes (fig. 32) at a cost of about \$250.

Logging-engine water tanks.—As a rule, either wooden or steel water tanks are mounted on the rear end of each logging-engine sled (fig. 14). The steel tanks,

which fit on a saddle, give the best service and cost from \$100 to \$200, depending on their capacity. A 5 by 8 foot steel tank costs about \$125. This tank is sometimes made in two compartments; one for oil, the other for water.

Straw drums.—The drum used to operate the straw line may be located on an extension of the main or trip drum shaft, or on the main drum shaft inside the frame. The cost of equipping an engine with a straw drum amounts to about \$150.

Loading drums.—When separate engines are not used for loading purposes, it is necessary to have a third friction drum on the yarding engines. On compound-g geared yarding engines this drum is located on the main drum shaft, either on the inside or outside of the frame.

On tandem-drum engines the most convenient location is on an extension of the main drum shaft. It is a narrow drum of relatively large diameter, which, having its own friction and brake, can be operated independently of the main drum. The cost of equipping an engine with this device amounts to about \$150.

Oil-burner equipment.—The approximate cost of full equipment for burning crude oil on yarding and roading engines and skidders is about \$450 for each machine; on loading engines, about \$375. These prices include the tank on the sled, which is used for the storage of both oil and water. The cost of maintenance of this equipment is about \$25 per year.

The oil is hauled from the storage tank to the tank on the rear end of the sled in tank cars, which have a capacity of about 7,000 gallons, and cost about \$1,000.

A large steel storage tank is erected at a convenient point on the logging railroad to receive oil in bulk. The cost of a 200,000-gallon steel storage tank, together with an 8-inch pipe and valves for filling, amounts to about \$4,000.

Electric signals.—Until very recently signals were universally given by means of a light wire attached to the whistle lever, the wire, either solid or twisted, being strung taut along the outer edge of the run from the engine to the rear of the chance. A solid signal wire costs about \$3; a twisted one, about \$10.

A large number of operators now use an electrical device which is connected with the lever of the whistle. The current is carried to the woods' end through insulated wires, which can be laid upon the ground or carried upon supports, as desired. Relays of push buttons along the line make it possible to give the signals at any point. Power to operate the whistle is furnished by from 6 to 12 dry batteries. The signal itself is the same as with the old method, and can be heard by the yarding crew, who thus know that the proper signal has been given to the engineer. The device eliminates the trouble of keeping a taut signal wire. It is claimed that the signals are transmitted more promptly than by the old method. One manager who is using the electric signal and who has a reputation for conservatism considers the device a "safety-first" appliance. Undoubtedly it will be universally used in the near future. The device complete for a yarding engine costs about \$100.

Blocks.—Figures 19, 20, 22, 27, and 33 indicate the types of blocks used in general yarding. A number of companies manufacture

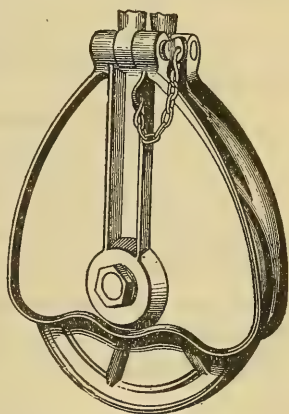


FIG. 33.—Moving block.

blocks, so that there is a large assortment for operators to select from.

Blocks of as large size as possible should be used. Wire-rope manufacturers recommend blocks with much larger sheaves than are practical in the woods. For 1-inch lines sheaves should not be less than 12 inches in diameter; and for $1\frac{1}{8}$ to $1\frac{1}{4}$ inch lines, from 14 to 18 inches. The standardization committee of the Pacific Logging Congress in 1913 recommended that blocks having sheaves of the following sizes be adopted:

Trip-line blocks:

- 9 by $1\frac{1}{4}$ by $1\frac{1}{8}$ inches, hub length 3 inches, grooved for a $\frac{5}{8}$ -inch line.
- 12 by $1\frac{1}{4}$ by $1\frac{1}{8}$ inches, hub length 3 inches, grooved for a $\frac{3}{4}$ -inch line.
- 14 by $1\frac{1}{2}$ by $2\frac{1}{16}$ inches, hub length 3 inches, grooved for a $\frac{3}{4}$ -inch line.
- 18 by $1\frac{1}{2}$ by $2\frac{1}{16}$ inches, hub length 4 inches, grooved for a $\frac{3}{4}$ -inch line.
- 24 by 2 by $3\frac{1}{16}$ inches, hub length 5 inches, grooved for a $\frac{3}{4}$ -inch line.

Yarding blocks:

- 10 by 2 by $2\frac{1}{2}$ inches, hub length 3 inches, grooved for a $1\frac{1}{4}$ -inch line.
- 12 by $2\frac{1}{2}$ by $2\frac{1}{8}$ inches, hub length $3\frac{1}{2}$ inches, grooved for a $1\frac{1}{2}$ -inch line.

Butt-chain blocks:

- 16 by 8 by $3\frac{1}{16}$ inches, hub length 8 inches, if grooved for a $1\frac{1}{2}$ -inch line.
- 20 by 8 by $3\frac{1}{16}$ inches, hub length 8 inches, if grooved for a $1\frac{1}{2}$ -inch line.
- 24 by 8 by $3\frac{1}{16}$ inches, hub length 8 inches, if grooved for a $1\frac{1}{2}$ -inch line.

The cost of blocks varies because of differences in the type, size, and make and because different material is used in their construction. The following tabulations give the type, size, and weight of blocks that are more or less standard, also the selling prices f. o. b. Portland in March, 1916. The material used in the construction of these blocks is indicated in the list of extra parts.

Butt-chain lead blocks (Fig. 25).

No.	Sheave.	Shaft.	Bearing.	Weight.	Net price.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	
1	24 by 8	$3\frac{1}{2}$	10	820	\$128.00
2	20 by 7	$3\frac{1}{2}$	10	650	102.00
3	16 by 7	3	10	475	72.00

Extra parts.

Items.	Net price.		
	No. 1.	No. 2.	No. 3.
Tool-steel shackle.....	\$18.80	\$17.20	\$15.25
Pair steel block sides.....	44.00	34.00	24.00
Case-hardened steel center shaft.....	6.00	6.00	6.00
Oil cup and nut with lock washer.....	1.40	1.40	1.40
Half nut with lock washer.....	.60	.60	.60
Bronze bushing.....	7.60	7.60	7.60
Manganese-steel sheave, bronze bushed.....	50.09	38.00	28.00

Moving blocks (Fig. 35).

No.	Sheave.	Pin.	Weight.	Net price.
	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	
1	14 by 3	3	230	\$45.00
2	16 by 3	3	270	49.00

Extra parts.

Items.	Net price.	
	No. 1.	No. 2.
Tool-steel shackle.....	\$3.60	\$3.60
Pair steel block sides.....	22.00	24.00
Casehardened steel pin.....	3.60	3.60
Half nut with lock washer.....	.65	.65
Bronze bushing.....	2.70	2.70
Manganese-steel sheave, bronze bushed.....	16.65	20.00

Yarding blocks (Fig. 30).

No.	Sheave.	Pin.	Diameter.	Weight.	Net price.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	
1	10 by 2½	2½	3	110	\$22.80
2	12 by 2½	2½	3	145	26.80

Extra parts.

Items.	Net price.	
	No. 1.	No. 2.
Tool-steel shackle.....	\$2.80	\$2.80
Pair steel block sides.....	7.60	7.60
Casehardened steel pin.....	2.80	9.60
Half nut and lock washer.....	.40	.40
Bronze bushing.....	1.80	1.80
Manganese-steel sheave, bronze bushed.....	8.80	11.20

Trip-line side or corner block (Fig. 23).

No.	Size.	Pin.	Hub.	Weight.	Net price.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	
1	9 by 1½	1½	2½	40	\$8.80
2	12 by 1½	2	3	55	12.00

Extra parts.

Items.	Net price.	
	No. 1.	No. 2.
Patent combination shackle with guard.....	\$0.60	\$0.80
Pair steel block sides.....	4.00	6.00
Casehardened steel pin.....	.80	1.80
Oil cup and nut with lock washer.....	.40	.45
Half nut with lock washer.....	.15	.25
Bronze bushing.....	.80	1.60
Manganese-steel sheave, bronze bushed.....	3.40	6.40

Trip-line head blocks (Fig. 22).

No.	Sheave.	Pin.	Hub.	Weight.	Net price.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	
1	14 by 1½	2½	3	95	\$17.60
2	18 by 1½	2½	4	140	26.00
3	24 by 2	3	5	235	44.00

Extra parts.

Items.	Net price.		
	No. 1.	No. 2.	No. 3.
Forged-steel shackle ¹	\$1.20	\$1.60	\$2.80
Pair steel block sides.....	7.20	9.60	18.80
Case-hardened steel pin.....	2.00	2.60	3.20
Oil cup and nut with lock washer.....	.60	.60	1.40
Half nut with lock washer.....	.40	.45	.60
Bronze bushing.....	1.60	2.00	3.60
Manganese-steel sheave, bronze bushed.....	7.60	12.20	20.00

¹ No. 3 has tool-steel forged shackle.

Table 11 gives the fixed investment in ground yarding blocks for one yarding engine. To allow for a proper range, the total cost and weight, including blocks of different sizes, is shown in three cases. The aim is to include a liberal amount of such equipment, taking into account the fact that the number of blocks needed for different yarding chances varies and that some blocks are undergoing repairs at times. This table can be easily modified to take care of a given set of conditions.

TABLE 11.—*Fixed investment in blocks for one yarding engine.*

Number.	Items.	Case 1.			Case 2.			Case 3.		
		Size.	Weight (pounds).	Net price.	Size.	Weight (pound).	Net price.	Size.	Weight (pound).	Net price. ¹
2	Butt chain blocks.....	24 by 8	1,640	\$256.00	20 by 7	1,300	\$204.00	16 by 7	950	\$144.00
2	Moving blocks.....	16 by 3	540	99.00	14 by 3	460	90.00	14 by 3	460	90.00
2	Yarding blocks.....	12 by 2½	290	53.60	10 by 2½	220	45.60	10 by 2½	220	45.60
1	Head trip block.....	24 by 2	235	44.00	18 by 1½	140	26.00	14 by 1½	95	17.60
1	Corner or side block.....	14 by 1½	96	17.60	14 by 1½	95	17.60	14 by 1½	95	17.60
8	Side blocks.....	12 by 1½	440	96.00	12 by 1½	440	96.00	12 by 1½	440	96.00
	Extra parts.....		400	100.00		300	75.00		250	50.00
16	Total.....		3,640	668.00		2,955	554.00		2,510	460.00

¹ Prices are those of March, 1916.

Yarding rollers.—Figure 28 shows a yarding or stump roller. The use of such rollers in connection with ground yarding is discussed on page 72. The method is also shown in figure 15. They weigh from 210 to 325 pounds and cost from \$45 to \$60.

Ground yarding lines.—Ground yarding lines are all made of wire rope, without which modern methods of logging could not have developed. Wire rope consists of a group of strands laid sym-

metrically around a center core, the strands consisting of wires twisted together symmetrically according to a definite geometrical arrangement. The unit of construction is the strand. While a large number of geometrical combinations are possible, the ordinary practice is to use 1 wire in the center of the strand and to surround it with 6 wires, then successively with layers of 12, 18, 24, and 36 wires, etc., the construction being known as the concentric strand. Six wires around a center wire produce a strand for a haulage rope. A supplementary layer of 12 wires makes a 19-wire strand for a hoisting rope. This strand in turn, when covered by a third layer of 18 wires, makes a 37-wire strand that is used in a special flexible hoisting rope. In strands of uniform diameter the greater the number of wires in the strand the more flexible the rope. The strands, usually 6 in number, are, as a rule, laid together around a hemp center.

The "haulage rope," 6 strands of 7 wires each, is a relatively stiff rope with large wires capable of resisting external wear. Its use is limited to conditions where there is much abrasion and little bending around sheaves. In the "hoisting rope," 6 strands of 19 wires each, the wires are smaller than those in a 6 by 7 rope, and are less able to resist abrasion, but can more easily be bent around sheaves and drums. The "special pliable rope," 6 strands of 37 wires each, is composed of still smaller wires than the 6 by 19, possesses greater flexibility, and may be bent around fairly small sheaves. It should not be subjected to much external wear, particularly in the smaller sizes, as the wires will be worn off quickly. The "extra pliable rope," 8 strands of 19 wires each, is more flexible than the 6 by 19, and may be used over smaller sheaves than the latter. It is about as flexible as 6 by 37 construction, but not so strong, owing to its larger hemp center.

The ropes so far referred to are of the one-size-wire construction. In the making of 6 by 19 rope certain features result from a slight modification of the strands and wires. In Seale construction the center wire of the strand is large, the next layer of 9 wires is small, and the outer layer of 9 wires large. These strands produce a rope somewhat stiffer than ordinary 6 by 19 construction and having a limited number of uses. The strands of another construction consist of wires of three different sizes, 7 inside wires of uniform diameter surrounded by 12 wires which are alternately large and small. This combination increases the metallic area and strength by approximately 10 per cent.

There are two general methods of laying up rope—the common type, known as regular lay, and Lang's lay. In the former the wires are twisted in one direction and the strands are laid into the rope in the opposite direction. Most of the rope made in America is

made in this manner, and it has become standard for general work. In the latter, the wires in the strand and the strands in the ropes are twisted in the same direction.

Wire ropes are made almost exclusively from iron or steel, and the materials used may be further grouped into three main divisions, viz, iron, crucible cast steel, and plow steel. The wire rope used for yarding lines is for the most part made from plow steel and special plow steel. These two classes of rope, besides being used for main, trip, and straw lines, are used for chokers and overhead yarding lines, the special plow steel being especially adapted for overhead work. For lines other than chokers a 6 by 19 construction with a hemp core is used. A small percentage of operators make their main yarding lines from rope that has a steel core.

The diameter and length of lines is discussed under the heading "Wire rope cost."

The selling price of wire rope, besides varying with the grade and type of construction, fluctuates with economic conditions. The list prices of manufacturers for the same grade and construction are the same. On March 8, 1916, the discount quoted by one wire-rope agent was 37½ per cent off the list prices. About two years ago the discount was about 60 per cent. Under normal conditions the discount is about 50 per cent.

The following tables give the net prices on wire rope of the grade and type of construction ordinarily used in logging operations. The prices are based on a discount of 50 per cent off the list. The strengths given are standard, being those adopted by the manufacturers on May 1, 1910.

TABLE 12.—*Standard plow steel hoisting rope.*
[6 strands, 19 wires to the strand, 1 hemp core.]

Net price per foot.	Diameter in inches.	Approximate weight per foot in pounds.	Approximate strength in tons of 2,000 pounds.	Proper working load in tons of 2,000 pounds.
\$0.06	$\frac{1}{4}$	0.10	2.65	0.53
.06025	$\frac{1}{4}$	.15	3.8	.76
.0625	$\frac{1}{4}$	.22	5.75	1.15
.065	$\frac{1}{4}$	.30	8	1.6
.07	$\frac{1}{4}$	.39	10	2
.08	$\frac{1}{4}$	.50	12.3	2.4
.095	$\frac{1}{4}$	.62	15.5	3.1
.13	$\frac{1}{2}$	.89	23	4.6
.17	$\frac{1}{2}$	1.20	29	5.8
.215	1	1.58	38	7.6
.27	1½	2	47	9.4
.325	1½	2.45	58	12
.395	1½	3	72	14
.465	1½	3.55	82	16
.54	1½	4.15	94	19
.65	1½	4.85	112	22
.73	1½	5.55	127	25
.79	2	6.3	140	28

NOTE.—The net prices given are based on a discount of 50 per cent off the list prices. Add 10 per cent to the list prices for wire center.

TABLE 13.—*Special plow steel hoisting rope.*

[6 strands, 19 wires to the strand, 1 hemp core.]

Net price per foot.	Diameter in inches.	Approximate weight per foot in pounds.	Approximate strength in tons of 2,000 pounds.	Proper working load in tons of 2,000 pounds.
\$0.065	$\frac{1}{4}$	0.10	3.15	0.63
.065	$\frac{1}{4}$	.15	4.50	.9
.0725	$\frac{3}{8}$	.22	6.75	1.35
.0775	$\frac{1}{2}$	.30	9.4	1.9
.085	$\frac{5}{8}$	.39	12.1	2.4
.095	$\frac{3}{4}$	.50	14.5	2.9
.1125	$\frac{7}{8}$	.62	19	3.8
.155	1	.89	26.3	5.3
.195	$1\frac{1}{8}$	1.20	35	7
.25	$1\frac{1}{4}$	1.58	45	9
.31	$1\frac{3}{8}$	2	56	11
.375	$1\frac{1}{2}$	2.45	69	14
.45	$1\frac{3}{4}$	3	84	17
.55	2	3.55	98	20
.65	$2\frac{1}{8}$	4.15	110	22
.80	$2\frac{1}{4}$	4.85	133	27
.875	$2\frac{3}{8}$	5.55	150	30
.925	2	6.30	166	33

NOTE.—The net prices given are based on a discount of 50 per cent off the list prices. Add 10 per cent to the list prices for wire center.

TABLE 14.—*Extra pliable plow steel hoisting rope.*

[8 strands, 19 wires to the strand, 1 hemp core.]

Net price per foot.	Diameter in inches.	Approximate weight per foot in pounds.	Approximate strength in tons of 2,000 pounds.	Proper working load in tons of 2,000 pounds.
\$0.06625	$\frac{1}{4}$	0.09	2.25	0.45
.0675	$\frac{1}{4}$	.13	3.35	.67
.07	$\frac{3}{8}$	.20	5.12	1.02
.075	$\frac{1}{2}$	.27	6.90	1.38
.08	$\frac{5}{8}$	.35	8.70	1.74
.09	$\frac{3}{4}$	.45	11.60	2.32
.105	$\frac{7}{8}$	.56	14	2.8
.145	1	.80	20	4
.19	$1\frac{1}{8}$	1.08	26	5.2
.24	$1\frac{1}{4}$	1.42	33	6.6
.30	$1\frac{3}{8}$	1.80	43	8.6
.36	$1\frac{1}{2}$	2.20	52	10.4
.435	$1\frac{3}{4}$	2.70	64	12.8
.515	2	3.19	74	14.8

NOTE.—The net prices given are based on a discount of 50 per cent off the list prices.

Table 15 indicates the fixed investment in ground yarding lines. To take care of different conditions, the total cost and weight is given for 24 cases, which include lines of different lengths, diameters, and grades.

TABLE 15.—Fixed investment in ground yarding lines.

Type of line.	Length.	6 by 19 plow steel.						6 by 19 special plow steel.					
		Diam-eter.	Weight.	Cost.	Diam-eter.	Weight.	Cost.	Diam-eter.	Weight.	Cost.	Diam-eter.	Weight.	Cost.
	<i>Fet.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>\$316</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>\$372</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>\$300</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>\$360</i>
Main.....	800	1 1/8	1,900	2,400	1 1/8	2,840	1,900	1 1/8	2,400	1,900	1 1/8	2,840	2,400
Trip.....	2,000	1 1/8	1,000	1,240	1 1/8	1,780	260	1 1/8	1,000	130	1 1/8	1,780	225
Straw.....	2,000	1 1/8	440	440	1 1/8	440	135	1 1/8	440	145	1 1/8	440	145
Straps.....			316	43		316	43		316	43		316	43
Total.....			3,716	598		5,376	810		3,716	678		4,396	773
Main.....	1,000	1 1/8	2,450	3,000	1 1/8	3,550	465	1 1/8	2,450	275	1 1/8	3,550	450
Trip.....	2,500	1 1/8	1,250	1,550	1 1/8	2,225	328	1 1/8	1,250	238	1 1/8	2,225	287
Straw.....	2,500	1 1/8	550	440	1 1/8	440	136	1 1/8	550	181	1 1/8	440	181
Straps.....			316	43		316	43		316	43		316	43
Total.....			4,566	724		6,531	989		4,566	837		6,531	1,161
Main.....	1,200	1 1/8	2,740	3,600	1 1/8	4,260	558	1 1/8	2,740	450	1 1/8	4,260	560
Trip.....	3,000	1 1/8	1,500	1,800	1 1/8	2,570	387	1 1/8	1,500	285	1 1/8	2,570	337
Straw.....	3,000	1 1/8	560	440	1 1/8	440	137	1 1/8	560	217	1 1/8	440	217
Straps.....			316	43		316	43		316	43		316	43
Total.....			5,216	860		7,686	1,178		5,216	995		7,686	1,285
Main.....	1,400	1 1/8	3,430	4,200	1 1/8	4,970	651	1 1/8	3,430	525	1 1/8	4,970	630
Trip.....	3,500	1 1/8	1,750	2,170	1 1/8	3,115	455	1 1/8	1,750	333	1 1/8	3,115	394
Straw.....	3,500	1 1/8	770	440	1 1/8	440	219	1 1/8	770	254	1 1/8	440	254
Straps.....			316	43		316	43		316	43		316	43
Total.....			6,266	997		8,841	1,368		6,266	1,155		8,841	1,609

NOTE.—Cost of lines is based on a net price for wire rope of 50 per cent off the list price.

Butt chains and butt hooks.—A butt chain or line (fig. 23) is a short connection by which the chokers are attached to the main yarding line. It consists of the main connecting link, either a heavy steel chain with short links or a wire rope with eyes spliced in each end, with a hook or clevis on the end which is attached to the main line and a swivel, a link, and a butt hook on the other. The swivel in the connection allows the log to roll when being pulled in without twisting the main line. Butt chains are made in different weights, depending upon the personal ideas of the operator and the conditions of the chance. They range from 5 to 8 feet in length. Where they are constructed of wire rope, sockets instead of splices may be used.

Besides the plain heavy butt hook there are a number of patented ones which are so constructed that the socket on the choker is locked in place and can not come out, as often happens with open hooks. This is an advantage which well repays for the extra cost.

Although not actually a part of the butt chain, the trip-line connection is usually considered as a part. It is attached to the same clevis as the butt chain by means of a link, a swivel, and another clevis. A hook may be used instead of a second clevis.

A butt chain without the hook costs about \$13 and weighs about 128 pounds. Tag lines are considerably lighter. Butt hooks ordinarily used cost from \$6 to \$15. Clevises cost from \$2.50 to \$3.50. Figure 26 shows one type of rigging plate which is used where two butt chains are used on connection with tag lines. This plate without clevises costs about \$4. The fixed investment in butt chains, butt hooks, and clevises used in connection with one yarding engine amounts to about \$100.

Chokers.—A choker (figs. 24 and 25) is a piece of wire rope which may be set on a log in such a way as to form a noose. There are two distinct forms, the flat-hook choker and the type with the hook running loose on the line. The flat-hook type consists of a piece of wire rope with an eye in one end and a flat hook attached to the other. The line is passed around the log and the flat hook is hooked over the line, making a noose. The other type consists of a piece of wire rope with eyes spliced in each end and a hook which runs loose on the line. The hook is slid along until it will hook into the end of the line, thus forming a noose. On rough ground this type does not come loose so quickly as the flat hook. The flat hook is easier to handle. The flat hook works better in high-lead yarding than in ground yarding, the tension on the line being more even. Forged-steel sockets are used to a great extent on the ends of the choker instead of spliced eyes, as they save time and some feet of line and are more durable. There are many styles of both flat and running hooks used.

The length of a choker depends on the size of the timber; the range is from 15 to 30 feet or more. When chokers are made from new rope, 8 by 19 construction is generally used, the diameter of the rope ranging from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches. Most chokers are made of $1\frac{1}{4}$ -inch rope. Choker hooks for $1\frac{1}{8}$ to $1\frac{1}{4}$ inch line cost from \$2.50 to \$10. The type shown in figure 24 costs about \$2.50 each. Sockets for $1\frac{1}{8}$ and $1\frac{1}{4}$ inch line cost about \$2.25 each. On this basis a 30-foot $1\frac{1}{4}$ -inch choker, with choker hook, costs about \$23 and weighs about 70 pounds.

The number of chokers in a set, or used in connection with one yarding engine, should vary with the character of the chance and the material from which they are made. For the purpose of this discussion eight chokers will be considered ample. It has been estimated that a 30-foot $1\frac{1}{4}$ -inch choker, with sockets and hook, costs about \$23. The chokers in a set are not of uniform length, however, and a 30-foot choker is longer than the average. For the purpose of estimating the fixed investment in chokers and choker hooks necessary for one yarding engine, an average length of 25 feet is assumed. On this basis the fixed investment amounts to about \$165.

Woods water system.—Two methods of supplying water for logging engines are used. The more common one is to convey the water to the engines in pipes; the other, in tank cars. Where water is plentiful it may be possible to supply all the engines through pipes by gravity at slight expense. Where the water is less plentiful it may be advisable to pump all the water used in the camp, in some cases by a central pumping station. Some operators haul the water in tank cars. At one three-side camp the water system, consisting of two steam pumps with boilers and 6 miles of pipe, cost \$4,000. It would seem that a camp water system should never cost more than this. The selling price of black pipe is approximately as follows:

	Per 100 feet.
$\frac{3}{4}$ -inch pipe	\$4. 15
$1\frac{1}{4}$ -inch pipe	6. 10
$1\frac{1}{2}$ -inch pipe	7. 30

Miscellaneous equipment.—In addition to the equipment listed above, a rather large amount of small equipment is necessary, such as splicing tools, saws, axes, sledges, wedges, clamps, swamp hooks, oil cans, wrenches, shovels, hoes, etc. The fixed investment in such equipment amounts to about \$250 per engine where one engine is operated; about \$200 where more than one engine is operated. These amounts are intended to take care of the equipment in use as well as the stock on hand.

INVESTMENT IN EQUIPMENT.

The following is a summary of the investment in yarding equipment in connection with one yarding engine in three cases. The cost does not include freight.

Summary of equipment for one yarding engine.

CASE 1.

Equipment.	Cost.
10 by 11 inch standard compound-gear ed yarding engine-----	\$3, 350
Repair parts and materials for yarding engine ¹ -----	100
Yarding engine sled-----	350
Fair-leaders-----	150
Extended fire box-----	250
Straw drum-----	150
Electric signals-----	100
Fuel-oil equipment and water tank-----	450
Blocks and extra parts-----	550
Yarding rollers-----	150
Ground yarding lines; 1,200 feet of 1 $\frac{1}{4}$ -inch main line; 3,000 feet of $\frac{3}{16}$ - inch trip line; and 3,000 feet of $\frac{3}{8}$ -inch straw line-----	995
Butt chains, butt hooks, and clevises-----	70
Chokers and choker hooks-----	165
Miscellaneous equipment-----	225
Total cost-----	7, 055

NOTE.—Statement includes equipment in use and in stock.

CASE 2.

Equipment.	Cost.
11 by 13 inch standard compound-gear ed yarding engine-----	\$4, 600
Repair parts and materials for yarding engine-----	210
Yarding engine sled-----	400
Fair-leaders-----	150
Extended fire box-----	250
Straw drum-----	150
Electric signal-----	100
Fuel-oil equipment and water tank-----	450
Blocks and extra parts-----	575
Yarding rollers-----	150
Ground yarding lines: 1,000 feet of 1 $\frac{3}{8}$ -inch main line; 2,500 feet of $\frac{5}{8}$ - inch trip line; and 2,500 feet of $\frac{3}{8}$ -inch straw line-----	955
Butt chains, butt hooks, and clevises-----	70
Chokers and choker hooks-----	175
Miscellaneous equipment-----	250
Total cost-----	8, 485

NOTE.—Statement includes equipment in use and in stock.

¹ Every operator finds it necessary to carry certain repair parts and materials in stock. While the value of these parts varies, it is thought that the amount given in the table is ample in most cases. One operator, employing 5 yarders, carried parts and materials in stock to the amount of \$1,700. This stock was made up of an extra guide and crank pin, brasses, valve stems, a steam gauge, gauge glasses, an extra cylinder head, a supply of valves for vulnerable parts of the engine, a small but complete set of pipe fittings and valves for water system, packing, etc.

CASE 3.

Equipment.	Cost.
12 by 14 inch standard compound-geared yarding engine-----	\$5,000
Repair parts and materials for yarding engine-----	220
Yarding engine sled-----	450
Fair-leaders-----	150
Extended fire box-----	250
Straw drum-----	150
Electric signal-----	100
Fuel-oil equipment and water tank-----	450
Blocks and extra parts-----	675
Yarding rollers-----	150
Ground yarding lines: 1,000 feet of 1½-inch main line; 2,500 feet of ¾-inch trip line; and 2,500 feet of ¾-inch straw line-----	1,161
Butt chains, butt hooks, and clevises-----	70
Chokers and choker hooks-----	185
Miscellaneous equipment-----	275
Total cost-----	9,286

NOTE.—Statement includes equipment in use and in stock.

COST.

Output.—Taking it straight through by camps, good and bad country, the ground yarding output, naturally the basic element in a cost computation, ranges between 40,000 and 80,000 feet per yarding engine per yarding day of 10 hours. A few camps average a little less than 40,000 feet, others average more than 80,000. For a short period the output may be considerably lower or higher. The largest volume of timber ever yarded in a day of 10 hours in this region amounted to 432,000 feet. The crew, on its mettle, was working in ideal natural conditions and with first-class equipment. A crew working in a particularly hard chance may get as little as 100,000 feet in one week; in a particularly good chance, as much as 1,000,000 feet in the same time.

The estimating of the average output in a given chance or set of conditions is extremely difficult and liable to error. It has been estimated that a yarding engine carrying 900 feet of line should average 45 logs, or from 67,500 to 90,000 feet per day in timber where the logs average from 1,500 to 2,000 feet to the log; 50 logs, or from 50,000 to 75,000 feet per day in timber where the logs average from 1,000 to 1,500 feet; 55 logs, or from 27,500 to 55,000 feet per day in timber where the logs average from 500 to 1,000 feet; and 65 logs, or about 30,000 feet per day in timber where the logs average less than 500 feet. These estimates were based on time records. One hour each day was allowed for moving yarding engines; four for the placing of chokers, unfastening of logs by the chaser, removing unmerchantable timber from the roads, hauling wood logs, changing lines, etc.;

two and one-half hours for the starts and stops to straighten the logs out in the roads; two and one-half hours hauling the main line in and out. Average ground conditions were assumed.

It is obvious that estimates made in this way are artificial and of questionable value. Yarding records can be found which indicate that the above estimates are in error. In fact, the man who made this estimate has since exceeded it in small timber.

Without doubt, experience of the right character is the best basis for estimating the yarding output with specific conditions. One can acquire a satisfactory basis for estimating yarding output through observation, including a careful examination of the different factors of each chance, together with an analysis of output records. In the following discussion of the labor cost, a body of such records is given, with the factors in the case stated as fully and accurately as possible.

Labor cost.—As a rule it is the labor cost only that is given under the heading "Yarding cost" in the logging cost statements of operators, for the labor constitutes the bulk of the yarding cost, though by no means all of it. Cost is largely determined by output, but the size of the crew and the wages paid also count.

Statements giving the average labor cost per thousand feet, because they vary so much and because it is so difficult to relate average costs to practical assumptions, are of little value. The following statements may afford some clew to this cost, but should not be taken too seriously:

Labor cost per thousand feet (ground yarding).

Average logs:

2,000 feet per log	\$0. 44
1,750 feet per log	. 50
1,500 feet per log	. 57
1,250 feet per log	. 64
1,000 feet per log	. 66
750 feet per log	. 87
500 feet per log	1. 15
250 feet per log	1. 50

[Based on the assumption that the logs averaged 1,200 feet in volume.]

Stand per acre:

20,000 to 40,000 feet	\$0. 64
40,000 to 60,000 feet	. 60
60,000 to 80,000 feet	. 57
80,000 to 100,000 feet	. 54

The number of men in a yarding crew is more or less fixed, but it can not be said that there is a standard crew. Foremen have different ideas of the proper size of a crew, and the members of the amount of work they should do. In addition, the size of the crew varies to

some extent in the same camp with the character of the chance; or the size of the timber, roughness and steepness of the ground, length of haul, amount of down timber, etc. When labor is scarce and hard to handle, operators not infrequently find it desirable to carry extra help in the rigging crew in order to provide for sudden vacancies.

The basis of employment and payment of labor in this region is a 10-hour day, with a charge for board. Hook tenders are sometimes paid by the month.

During certain years, or parts of years, wages are higher than in others. At a given time some camps pay 8 to 10 per cent more per day per man than others. In some camps some of the men, because of special fitness or length of service, receive a larger compensation than others for the same class of work. For these reasons it is difficult to give the average wages paid the different members of the yarding crew.

The following list is intended to approximate the wages—average, high, and low—paid the labor working in ground yarding crews by the logging companies in the region during the past six years:

Approximate wages of ground yarding crews.

Position.	Wages per day.		
	Average.	High.	Low.
Hooktenders.....	\$5.25	\$6.00	\$4.50
Rigging slingers.....	3.50	3.75	3.25
Choker men.....	3.25	3.50	3.00
Chasers.....	3.25	3.50	3.00
Swampers.....	3.00	3.25	2.75
Snipers.....	3.00	3.25	2.75
Signalman.....	2.75	3.00	2.50
Engineer.....	3.50	3.75	3.25
Fireman.....	2.50	2.75	2.25
Wood buck.....	2.50	2.75	2.25

The wages given in the column headed "Low" are not the lowest wages that have been paid. Camps that have paid the wages included in the column headed "Average" paid the following wages in October, 1915:

	Per day.
Hook tenders.....	\$3.50
Rigging slingers.....	2.75
Choker men.....	2.50
Chasers.....	2.50
Swampers.....	2.25
Snipers.....	2.25
Signalman.....	2.00
Engineer.....	3.00
Fireman.....	2.00
Wood buck.....	2.25

A few operators find it economical now and then to run a side by contract, in which case the operator may furnish everything except the labor; or he may furnish only the large equipment, the contractor furnishing the labor, supplies, etc.

A few camps use bonus or profit-sharing systems. As a rule, the system consists in setting a standard output and allowing all the members of the yarding crew, or certain members of the yarding crew who have been in the employ of the company a certain length of time, a certain amount per thousand feet in addition to their regular wages for every thousand feet yarded in excess of the standard. The regular wages may equal the wages the company would pay if they were not using a bonus system, or they may be less.

The company pays a bonus to only those men who are directly connected with the handling of the logs from the stump to the car, such as hook tenders, chasers, rigging slingers, and signalmen, eliminating such men as wood bucks, swampers, snipers, etc. Wages comparable with the wages paid in camps that are not using a bonus system are paid, regardless of whether the standard output is made or exceeded. Those members of the crew who are working under the bonus system are paid an additional amount as bonus when the yarding output exceeds the standard output, as follows: For each 1,000 feet of daily average output above the standard the wages of the men are increased 1 per cent. The standard is set by the logging superintendent for each chance monthly, or as often as conditions require. In establishing the standards, it is the stated aim of the company to put them where they can be made by an average crew without undue effort.

It is unusual to find a camp where all the logs are yarded direct to the landing, as many operators find it necessary to do a little double hauling, others a great deal. For this reason it is difficult to secure specific costs for direct yarding. The following costs are given more for the purpose of illuminating the subject than to give exact knowledge:

(1) The labor cost of transporting the logs from the stump to the landing, practically all single hauling, at a camp along the Columbia River in 1912, amounted to \$0.69 per thousand feet.

This cost includes a part of the wages of the camp foreman, one-half the wages of the timekeeper, and all the wages of the scaler. It does not include the cost of moving the yarders from one landing to another, the taking in and the setting of lines when moving, the grading of yarder settings, or any phase of the loading of the logs. The following men were employed:

	Wages per day.
Hook tender.....	\$6. 00
Rigging slinger.....	4. 00
Rigging slinger.....	3. 50
Rigging slinger.....	3. 25
Sniper.....	3. 00
Chaser.....	3. 25-3. 50
Signalman.....	2. 50
Butt chain block tender.....	3. 25
Fireman.....	2. 75
Wood buck.....	2. 50
Woodchopper.....	2. 50
Engineer.....	4. 00
Log brander.....	2. 50

During a part of the year oil was burned in two of the three yarders, which reduced the crew of the oil-burning yarders by three men, viz, the fireman, wood buck, and woodchopper. The number and wages of the men, of course, varied some.

The yarding chances from the standpoint of the ground were for the most part as good as can be found in this region, the average maximum yarding distance amounting to about 800 feet. Seldom, if ever, was the ground steep enough to cause the logs to run. Not less than two logs were yarded at a turn, sometimes three or four, and occasionally as many as five.

The forest is about 150 years of age and is cutting about 80,000 feet per acre, the trees averaging about 28 inches in diameter at breast height. About 95 per cent of the stand is Douglas fir, the rest hemlock.

The yarders were 10 by 11 inch, compound-gearred engines, up-to-date in design, in good repair, and were driven at practically their maximum speed.

Yarders Nos. 1 and 2 handled longer logs than yarders No. 3, which was due to different methods of marketing. Logs 90 feet or more in length were yarded by these two yarders, the average length amounting to 60 feet. The maximum lengths handled by yarder No. 3 were 40 feet, averaging about 36 feet.

The effect of handling long logs is shown in the following summary of the yarding output. It will be noted that the daily output of yarder No. 3, which handles short logs, was 15,000 feet less than that of yarder No. 2, and 17,000 feet less than yarder No. 1. While it can not be claimed that the difference in output was entirely due to differences in the log lengths, similarity in the logging chances, methods, equipment, and the like, suggest strongly that this is the reason. The three yarders were of the same size, make, and age. The chances from the standpoint of timber, ground, and yarding distances were practically the same, and the average daily outputs

of yarders Nos. 1 and 2 were practically the same, both from the standpoint of volume and the number of logs.

TABLE 16.—*Summary of yarding output.*

Yarder.	Number of logs.	Number of machine days.	Total scale.	Average number of logs per day.	Average volume of logs.	Average daily output.
			<i>Feet.</i>		<i>Feet.</i>	<i>Feet.</i>
No. 1.....	27,912	253½	19,664,124	118	705	83,679
No. 2.....	26,062	230½	18,789,422	113	721	81,692
No. 3.....	25,246	179	11,848,857	141	469	66,220
Total.....	79,220	662¾	50,302,403	372	620	231,591

Average length of logs.....	Feet.
Average number of logs per yarder per day.....	51
Average output per yarder per day.....	119
	77,197

(2) The labor cost of transporting the logs from the stump to the cars, practically all single-hauling, at a camp on the flat to the west of the Cascades in Washington in 1912, amounted to \$0.965 per thousand feet. It includes the cost of yarding, moving donkeys, changing lines, raising gin poles, loading, and laying and lifting spur railroad track. It is unusual to segregate the cost of laying and lifting track in this way. A gin pole was used in loading, the power being furnished by a drum on the yarder. The following gives the yarding and loading crew:

	Wages per day.
Hook tender.....	\$4.50 to \$5.00
Rigging slinger.....	4.00 to 4.50
2 choker men.....	3.00 to 3.25
Sniper.....	3.00 to 3.25
Knotter.....	2.75 to 3.00
2 swampers.....	2.75 to 3.00
Signalman.....	2.50 to 2.75
Chaser.....	3.00 to 3.25
Engineer.....	3.50 to 3.75
Fireman.....	2.50 to 2.75
Wood buck.....	2.50 to 2.75
Drum tender.....	3.00 to 3.25
Head loader.....	4.00 to 4.50
1 second loader.....	3.00 to 3.25
Section hands.....	2.50 to 2.75

The ground was practically level, never steep enough to cause the logs to run, quite free of ravines and pot holes, with little brush or down timber. It was seldom necessary to yard the logs more than 800 feet—the average maximum yarding distance being about 650 feet.

The timber, which was cutting out from 85,000 to 90,000 feet per acre, was second growth, dense, of good height, averaging about 30

inches in diameter at breast height. The logs averaged 550 feet in volume.

The engines were $10\frac{1}{2}$ by $10\frac{1}{4}$ inch compound-g geared yarders, equipped with loading drum.

The average output per yarder per yarding day was 58,500 feet, selling scale. The time on which this average is based includes the time consumed in moving the yarders from one setting to another, changing ends, raising gin poles, changing lines, etc., as well as the time consumed in transporting logs from the stump to the landing.

(3) The labor cost of transporting the logs from the stump to the landing, including single and double hauling, at a camp along the Columbia River in 1912, amounted to \$0.746 per thousand feet. It is not possible to state exactly the proportion of timber double hauled. The amount, however, ranged from one-third to one-half of the total output.

This cost includes a part of the wages of the camp foreman, time-keeper, and bookkeeper, and all the wages of the scaler. It does not include the cost of moving the logging yarders from one setting to another, loading, or the construction of pole roads and landings.

The following crew was employed:

	Wages per day.
Hook tender.....	\$5.00 to \$6.00
Head rigging slinger.....	3.75 to 4.25
3 assistant rigging slingers.....	3.00 to 3.50
Sniper	3.00 to 3.25
Chaser	3.00 to 3.25
Signalman.....	2.50
Engineer	3.50

At times it was necessary to use four instead of three rigging slingers, besides the head rigging slinger, also an extra chaser and butt-chain-block man. Oil was burned in the machines at the landings. When double hauling, the following additional men were employed:

	Wages per day.
Engineer.....	\$3.50
Chaser.....	3.25
Fireman	2.75
Wood buck.....	2.50

The average output delivered at the landing per yarding day amounted to 70,000 feet. The fact that part of the timber was double hauled should be taken into consideration when analyzing this statement. While it is the aim in double hauling so to place the logging engines that the swinging crew can handle the output of the yarding crew without delaying them, such is not always the case. There is no question that the yarding record would have been higher if all the logs had been yarded direct to the landing.

The country is mountainous, very rough, and badly broken up. The slopes in general are steep. No rock outcrops or cliffs were encountered.

About 100,000 feet of Douglas fir, spruce, cedar, and hemlock per acre were logged, 20,000 to 30,000 feet of hemlock being left standing. The logs averaged about 36 feet in length and 1,900 feet in volume when based on the camp scale, which was about 2 per cent lower than the selling scale.

The three yarders used during the year were compound geared, new, and up to date. Two of them were 10 by 13 inch; the other, 11 by 13 inch.

TABLE 17.—*Summary of yarding record.*

Species.	Scale.	Number of logs.	Volume of average log.
	<i>Feet, b. m.</i>		<i>Feet.</i>
Douglas fir.....	32, 204, 222	14, 369	2, 241
Spruce.....	829, 157	497	1, 667
Cedar.....	2, 868, 684	2, 665	1, 076
Hemlock.....	1, 868, 065	2, 301	819
Totals.....	37, 770, 128	19, 832	1, 900

Number of yarding days.....	531
Average scale per yarding day.....	feet. 151, 797
Average scale per yarder per day.....	do.. 71, 164
Average number of logs per yarder per day.....	37
Average scale per log.....	feet. 1, 904
Culls and other logs not scaled.....	405

(4) The average labor cost of transporting the logs from the stump to the landing at a camp along the Columbia River in 1912 amounted to \$1.189 per thousand feet. It is not possible to state the average distance from the stump to the landing. A large percentage of the timber was double hauled; some of it was triple hauled.

The chance from the standpoint of the ground was about an average one, as the country is not particularly rough or badly broken up. From the standpoint of brush, rotten stumps, and down timber it was a bad one. The average minimum yarding distance was about 900 feet.

About 45,000 feet per acre were cut, mostly hemlock. The trees averaged about 32 inches in diameter at breast height. On the average three 32-foot logs were cut from a tree.

The average output per yarder per yarding day amounted to 57,000 feet, the logs averaging about 650 feet in volume. The yarding time on which this output was based includes breakdowns, moves, etc., which did not take more than five hours.

The crew consisted of 1 hook tender, 2 rigging slingers, 2 choker men, 1 signalman, 1 sniper, 2 chasers, 1 engineer, 1 fireman, 1 wood buck, and 1 branding man.

(5) The average labor cost for yarding and loading at a camp on the west foothills of the Cascades in Washington in 1912 was \$1.379 per thousand feet. This includes the cost of raising gin poles, but not the cost of constructing landings. The yarding and loading crew was made up as follows:

	Wages per day.
Hook tender.....	\$5. 00
Rigging slinger.....	3. 50
Two choker men.....	3. 25
Signalman.....	3. 75
Sniper	3. 00
Swamper	3. 00
Chaser	3. 25
Butt-and-chain-block tender.....	3. 25
Engineer	3. 75
Fireman	2. 50
Drum tender.....	3. 00
Head loader.....	4. 50
Second loader.....	3. 50

A gin pole was used for loading, power for loading being furnished by a drum on the yarder. Oil was used as fuel, but the services of a fireman were considered necessary. The fireman received one-fourth of a day's wages for firing up. The average output per yarder per yarding day was 37,500 feet.

The ground was both hilly and level. All the timber was yarded direct to the landing, that on the slopes being yarded downhill.

Forty-five per cent of the timber was cedar, the rest Douglas fir and hemlock. The logs averaged about 36 feet in length and 1,000 feet in volume.

Wire rope.—Most operators keep a wire-rope account, in which they include the cost of all wire rope used in the camp. A few camps classify this account into the headings "Wire rope" and "Rigging," including the cost of the rope used for main yarding, trip, straw, and loading lines other than crotch lines, under the former heading, and chokers, together with tag, yarding, and crotch lines, etc., under the latter. One can not determine from their records the respective costs of yarding, roading, and loading lines. Furthermore, the average cost arrived at at the end of the year, or some other period, is of necessity based on the inventory, which may be high or low. In many cases the operators get out monthly cost statements, including an amount for wire rope which is based on an estimate rather than on an inventory made up at the end of the month. Other camps ignore the value of the rope on hand and base the costs on purchases. This does not represent the true cost, and is misleading when one is not acquainted with the method used. At one camp where this latter method was used the wire-rope cost per thousand feet by months for

a period of five months was as follows: January, \$0.882; February, \$0.276; March, \$0.109; April, \$0.053; May, \$0.159.

The average cost per thousand feet of the wire rope used in transporting and loading logs to operators that deliver their output to tide-water or the Columbia River amounts to about \$0.15. The average cost by certain regions in accordance with the above is as follows:

	Per 1,000 feet.
Puget Sound.....	\$0.14
Columbia River.....	.15
Grays Harbor.....	.19
Willapa Harbor.....	.20

The above figures are based on a large number of camps and in no case on less than a year's time. The average cost for the Puget Sound region is based on 20 camps and an output of 896,000,000 feet. In this region the lowest cost for any camp was \$0.07; the highest, \$0.27. The cost at 7 camps ranged from \$0.10 to \$0.12; at 4 camps, from \$0.13 to \$0.15; and at 5 camps, from \$0.16 to \$0.19. The average cost for the Columbia River is based on 10 camps and an output of 385,000,000 feet. In this region the lowest cost for any camp was \$0.08; the highest, \$0.23. The cost at 3 camps ranged from \$0.10 to \$0.12; at 2 camps, from \$0.13 to \$0.15; at 4 camps, from \$0.16 to \$0.25. In the Grays Harbor and Willapa Harbor regions a great deal of long-distance pole-road roading is done, which explains the relatively higher costs. In these regions the highest cost was \$0.30; the lowest, \$0.13.

The cost of wire rope per thousand feet is a rather large item of expense, and varies considerably in different camps. The reasons for this variation are to be found in the following factors:

(a) *Life of lines*.—Generally speaking, main yarding lines should handle three, four, or five million feet. If a line is defective or the yarding chance is particularly bad, it may not serve to yard 2,000,000 feet. Not infrequently, because of defects, main yarding lines have to be discarded before they have handled as much as 1,000,000 feet. Occasionally, 10,000,000 feet or more are yarded with a main yarding line. Taking it straight through the region, in good and bad chances, main yarding lines possibly average 4,000,000 feet. They last longer as a rule in road (short haul on the ground) or swing work than in yarding work. Trip lines last longer than yarding lines. Some logging superintendents estimate that they last no longer; others, that they last nearly twice as long.

At one camp the main yarding lines used during one year averaged about 4,000,000 feet per line. Eight million feet were yarded with one main yarding line. One main yarding line lasted three weeks, another only two days. They were 1 $\frac{3}{8}$ -inch lines. The country is mountainous and badly broken up, and the slopes for the most part are steep. The logs were moved both uphill and down. They

averaged about 2,000 feet and were yarded an average maximum distance of 900 feet. At another camp the main yarding lines used during a year averaged 5,000,000 feet. They were $1\frac{1}{8}$ -inch lines. The ground was practically level and quite free of down timber. The logs averaged about 550 feet in volume. At still another camp the $1\frac{1}{4}$ -inch main yarding lines used during a year averaged 4,500,000 feet; the $\frac{5}{8}$ -inch trip lines, 5,500,000 feet. The ground was badly broken up by potholes, hummocks, small ravines, etc. The topography was mixed, the ground being both hilly and level; where it was hilly, the logs were moved downhill. The volume of the average log was about 1,000 feet, and the average output per engine per yarding day about 40,000 feet.

(b) *Diameter of lines.*—The size of lines used determines to a great extent their total cost and their life.

The following recommendations have been made:

That a $1\frac{1}{4}$ -inch main yarding and a $\frac{7}{8}$ -inch trip line should be used on 10 by 11 inch compound-gear'd yarding engines; a $1\frac{3}{8}$ -inch main yarding and a $\frac{3}{4}$ -inch trip line on 11 by 13 inch compound-gear'd yarding engines; a $1\frac{1}{2}$ -inch main yarding and a $\frac{11}{16}$ -inch or a $\frac{3}{4}$ -inch trip line on 12 by 14 inch compound-gear'd yarding engines; and that a $\frac{3}{8}$ -inch straw line be used on all engines.

It was assumed that a 10 by 11 inch engine would be used in comparatively level country where the difference in elevation would not exceed 75 feet, the largest log would not exceed 1,000 feet, and the maximum haul would not exceed 950 feet; that a 11 by 13 inch engine would be used in rolling country where the difference in elevation would not exceed 150 feet, the maximum log would not exceed 5,000 feet, and the maximum haul would not exceed 1,000 feet; that a 12 by 14 inch yarding engine would be used where conditions were more severe; and that the yarding would be done uphill whenever possible. These sizes are larger than those generally used. It may be, however, that the increased output will more than offset the additional cost for slightly larger cables.

As a rule the size of main-yarding lines ranges from $1\frac{1}{8}$ to $1\frac{3}{8}$ inches; of trip lines from $\frac{1}{2}$ to $\frac{7}{8}$ inches. In one camp, where the logs yarded averaged about 2,000 feet, the country being mountainous and badly broken up, $1\frac{3}{8}$ -inch main yarding and $\frac{7}{8}$ -inch trip lines were used. In another camp, where the logs yarded averaged about 600 feet, the country being practically level, yarding lines were $1\frac{1}{4}$ -inch and trip lines $\frac{1}{2}$ inch. In a third camp, where conditions were practically the same as those in the preceding camp, $1\frac{1}{8}$ -inch main yarding and $\frac{5}{8}$ -inch trip lines were used. In another camp, where the logs yarded averaged about 1,000 feet and the country was bad, the main yarding and trip lines were $1\frac{1}{4}$ -inch and $\frac{3}{4}$ -inch, respectively. In still another camp the following lines were used: A $1\frac{1}{8}$ -inch main line and a $\frac{5}{8}$ -inch trip line with a compound-gear'd engine; a $1\frac{1}{4}$ -inch

main line and a $\frac{3}{4}$ -inch trip line with a 11 by 13 inch compound-gear engine; and a $1\frac{1}{4}$ -inch main line and a $\frac{7}{8}$ -inch trip line with a scraping engine.

(c) *Cost per foot.*—The cost of wire rope per foot varies considerably, depending on the type of construction, the grade of material used, and economic conditions. For selling prices see "Ground yarding equipment."

(d) *Length of lines.*—It is obvious that the cost per thousand feet depends on the length of the lines; that it is larger where long lines rather than short ones are used. Main lines used in yarding range in length from 900 to 1,500 feet, averaging about 1,200 feet. Trip lines are about two and one-half times as long as the main yarding lines; straw lines, as long as trip lines.

(e) *Number of lines.*—If much of the timber has to be double hauled over the ground, the cost of wire rope per thousand feet is considerably higher than where it is all single hauled. If some of it has to be handled by three or more engines, the effect is to increase further the wire-rope cost.

(f) *Ground conditions.*—The lay of the land and the character of the soil has a direct bearing on the wire-rope cost. Steep, broken, rocky ground is harder on lines than comparatively level land with clay for the lines to work on.

(g) *Care of lines.*—The cost of wire rope depends to a great extent on the care given the lines. More attention is paid to the main yarding lines than to the others. There are few operators who do not keep pretty close track of the main yarding lines. There are not many who can tell if the other lines are giving good service, and yet the cost of the main yarding lines represents only about one-half of the wire-rope cost. All operators do not exercise as much care as possible in stringing out the trip lines to the end that friction may be reduced to a minimum. Some operators prolong the life of the main yarding line through frequent splicing or by turning the line end for end on the drum.

The effect of most of the factors mentioned above is shown by the following table and the accompanying discussions:

TABLE 18.—*Cost of wire rope.*

Camp.	Time.	Year.	Cost per thousand feet.
1.....	6 months.....	1912	\$0.072
2.....	1 year.....	1912	.108
3.....	1 year.....	1912	.197
4.....	1 year.....	1911	.15
	1 year.....	1912	.142
	1 year.....	1912	.229
5.....	1 year.....	1911	.403
	1 year.....	1910	.495

The cost at camp 1 includes the wire rope used in yarding and loading, including the rope used for chokers, tag lines, straps, etc. Straw lines were not used. One and one-eighth-inch rope was used for the main yarding lines; one-half-inch rope for the trip lines. Logs were single hauled a maximum distance of about 900 feet. The ground was practically level, quite free of pot holes and down timber, and contained little rocky material. The logs averaged about 550 feet in volume, and 10 by 11 inch yarding engines were used. A gin pole and crotch line were used in loading, the motive power being furnished by a drum on the engine.

The cost at camp 2 includes the wire rope used for the main yarding, trip, and main loading lines. It does not include chokers and tag lines used in yarding, and the crotch lines used in loading, which cost \$0.045 per thousand feet. One and one-fourth-inch rope was used for the main yarding lines, five-eighths-inch rope for the trip lines, 1½-inch rope for the loading lines. All the timber was single hauled an average maximum distance of about 800 feet. The ground was practically level and contained no rocky material. Not less than two logs were yarded at a trip, sometimes three or four, and occasionally as many as five. The yarding engines were driven at practically their highest speed, so that, relatively speaking, the lines had hard usage. The logs averaged about 600 feet in volume. The yarding engines were 10 by 11 inch, compound-gear.

The cost at camp 3 includes the wire rope used in yarding and loading, also chokers, tag lines, crotch lines, etc. All timber was yarded direct to the landing at an average maximum distance of about 800 feet. The ground was of mixed topography, being badly broken up as regards minor features. The logs, averaging 1,000 feet in volume, were never moved uphill.

The cost at camp 4 includes the wire rope used for main yarding, trip, and main loading lines. It does not include the cost of rope used for chokers, tag lines, etc., used in yarding, and crotch lines used in loading. The chance, from the standpoint of the ground, was an average one, as the country is not particularly rough or badly broken up. From the standpoint of brush, rotten stumps, and down timber, it was much worse than the average. Part of the timber was double hauled, just how much is not known. The volume of the average log was about 675 feet.

The cost at camp 5 in 1912 includes the wire rope used for main yarding, trip, and main loading lines. It does not include the cost of chokers, tag lines, etc., used in yarding, and crotch lines used in loading, which cost \$0.064 per thousand feet. One and one-fourth and 1½-inch rope were used for the main yarding lines; ¾-inch rope for the trip lines. The country is mountainous and badly broken up, the slopes being generally steep. Logs were moved both uphill

and downhill. No rock was encountered. The logs, averaging 1,800 feet in volume, were yarded an average maximum distance of 900 feet. About one-third of the timber was double hauled. The average scale per engine per yarding day was 70,000 feet. The cost for 1911 included all the wire rope used in camp. It is not possible to state the average maximum distance from the stump to the landings. Most of the timber was moved 2,000 feet by logging engines, a considerable amount 4,000 feet and a small amount 7,500 feet. The cost for 1910 includes the same items as the cost for 1911.

In estimating the cost of wire rope in connection with timber-appraisal work, two methods may be used. The first is to use the actual cost per thousand feet in a camp where conditions are approximately the same as the case being dealt with. The second is to develop the average cost in a more or less hypothetical way. A third method would be to check the results given by the second against the first. The following tables illustrate the second method in connection with single hauling.

TABLE 19.—*Estimated cost by second method.*

CASE 1.

Kind of line.	Size.	Length.	Cost per foot.	Cost per line.	Freight.	Total cost.	Output.	Cost per 1,000 feet.
	<i>Inches.</i>	<i>Feet.</i>	<i>Cents.</i>	<i>Dollars.</i>	<i>Dollars.</i>	<i>Dollars.</i>	<i>Feet.</i>	<i>Dollars.</i>
Main yarding.....	1½	1,200	32.50	390.00	7.35	397.35	4,000,000	0.093
Trip.....	1½	2,500	8.00	170.00	3.00	173.00	8,000,000	0.0216
Straw.....	1½	2,500	6.25	156.25	3.00	159.25	25,000,000	0.006
Total.....				716.25	13.35	729.60		0.1206

CASE 2.

Main yarding.....	1½	1,200	40.00	480.00	9.00	489.00	4,000,000	0.1220
Trip.....	1½	2,500	10.00	250.00	3.88	253.88	8,000,000	0.0317
Straw.....	1½	2,500	6.25	156.25	3.00	159.25	25,000,000	0.006
Total.....				886.25	15.88	902.13		0.1597

Rigging.—While it is the practice of most operators to include in the wire-rope account all the wire rope used, a few operators keep a rigging account, in which they may include crotch lines used in loading, yarding (not main yarding), and tag lines used in yarding, chokers, and straps.

It is not possible to discuss the cost of rigging per thousand feet except in a general way, largely because operators as a class have paid little attention to keeping records of this expense.

The maintenance or replacement of chokers is the largest item of expense in a rigging account and varies with conditions the same as the cost of main yarding lines, and for the same reasons. The

cost is higher where practically all chokers are made from new rope than where one-half or more of the chokers are made from old main yarding lines. Taking it straight through the region, the cost per thousand feet for chokers used in connection with ground yarding probably ranges from \$0.03 to \$0.05, the cost in hard chances running a little higher. The cost of tag and yarding lines, straps, etc., amounts to about \$0.01 per thousand feet. Loading lines are discussed under "Loading."

The cost of rigging, including chokers, tag lines, yarding lines, etc., and not including the main loading line, at one camp amounted to \$0.064 per thousand feet. It would seem that the cost should never be higher than this. The country was mountainous and badly broken up, the slopes for the most part being steep. Logs were moved both up and downhill. The yarding engines were powerful and output was not sacrificed to reduce the wear and tear on equipment. The logs averaged about 1,850 feet in volume. Most of the rigging was made from new wire rope. The cost of rigging, including chokers, tag lines, crotch lines, etc., and not including the main loading lines, at another camp amounted to \$0.044 per thousand feet. The country was not particularly rough or badly broken up. The logs averaged about 700 feet in volume, one, two, three, or four logs being brought in at a trip, depending on conditions. The yarding engines were powerful and driven at high speed, most stress being laid on output. The rigging for the most part was made from new rope. At another camp the cost of rigging, including chokers, tag, yarding, and crotch lines, etc., and not including main loading lines, amounted to \$0.057 per thousand feet. The country was practically level. Never less than two logs were yarded at a trip, sometimes three, four, or five. The logs averaged about 700 feet in volume. The yarding engines were driven at high speed.

Blocks, hooks, and rollers.—Very few operators keep account of the replacement and maintenance cost of blocks, hooks, and rollers. It does not, however, amount to much, ranging from \$0.02 to \$0.03 per thousand feet, including labor, repair parts, and materials.

At one camp the replacement and maintenance cost of blocks, hooks, and rollers used in yarding and loading amounted to \$0.024 per thousand feet. The country was mountainous and badly broken up, the slopes for the most part being steep. Logs were moved both uphill and downhill. About one-third of the timber was double hauled. The logs, which averaged about 1,900 feet in volume, were yarded an average maximum distance of about 900 feet.

Fuel.—Most operators use wood for fuel in ground yarding engines; a considerable number, fuel oil; and a very limited number, coal. The use of wood is about the same in other methods of yarding and in swinging and roading.

Until quite recently wood has been the common fuel for logging engines. It was close at hand, was seemingly cheap, easy on the flues, and gave sufficient steam. With the modern, high-speed, powerful logging engine, even with an enlarged fire box, it did not prove so satisfactory, and, with the advent of equipment that made the use of oil a practical matter, it began to give way to fuel oil.

The amount of wood consumed in a logging engine in a day depends on the amount of work done and the character of the wood, and varies considerably. This is also true of the cost, although it does not vary to such an extent, since certain costs are comparatively fixed. Regardless of the amount of wood consumed, a fireman and wood buck are needed at each yarding engine. One operator logging in large Douglas fir and using sound fir—most of it large—for fuel, kept a record and found that 1,650 feet of timber was consumed by each yarding engine per day. He was working the engines hard. This same operator estimated that it cost \$18.13 per day to supply steam for a yarding engine working under ordinary conditions when using wood, on the basis of the following assumptions:

Average daily wood consumption, 1,650 feet.

Average stumpage value, \$3 per 1,000 feet.

Average logging cost, \$4 per 1,000 feet.

Additional logging cost for wood logs, \$0.50 per 1,000 feet.

One fireman, \$3 per day.

One wood buck, \$2.75 per day.

Another operator estimated the fuel cost per yarding engine, per day, when using wood, at from \$14 to \$18.

In some camps, cull logs are utilized as fuel. Where this is the case, it would not be proper to include an item for stumpage in estimating the cost of fuel. Most camps, however, find it necessary to use sound logs because there is not a sufficient number of cull logs, or because the desired head of steam can not be held when certain classes of cull logs are used.

Several advantages are claimed for oil as fuel in logging engines. One is that it practically eliminates the fire hazard. Burning oil gives off few sparks, so that the danger always present in the dry season with wood or coal burning engines belching forth a cloud of fire-distributing sparks, is practically done away with. Under most conditions oil is cheaper. It is further claimed that the output per engine is from 15 to 25 per cent higher. This would be particularly true where large logs are moved uphill rather long distances. Until quite recently, however, loggers, as a class, have felt that oil was harder on the flues than wood, and there evidently were grounds for this belief. Through improvements in the burners, certain changes in the engines, devices for cleaning the flues, etc., this objectionable feature has seemingly been entirely or practically overcome, since

at the present time, 35 large operators are using oil in their logging engines—the total number of installations amounting to about 140. Oil has not met with much favor as a fuel for logging engines working at points other than along railroads, particularly in the winter-time, since the oil has to be pumped out to these engines. Then, there are camps located away from the railroads and away from deep water that can not use it for the simple reason that they can not secure it. The delivery cost in other cases no doubt precludes its economic use. In August, 1916, the price of oil in bulk at Tacoma, Seattle, and Portland, was \$1.20 per barrel; in the winter of 1914, \$0.80 per barrel—a barrel of oil contains 42 gallons and weighs 325 pounds.

The amount of oil burned in a logging engine varies with the amount of work done and the care exercised in firing. It varies from 6 to 8 barrels per day with yarding engines, and is a little less in engines engaged in roading or swinging where the haul is relatively short and in overhead yarding. Probably not more than half this amount is consumed in loading engines.

An operator using three yarding engines—two $10\frac{1}{2}$ by $10\frac{1}{4}$ inch and a 12 by 12 inch—stated that each engine consumed about 8 barrels of oil per yarding day. The average output of each engine per yarding day was about 80,000 feet, the maximum yarding distance amounting to 900 feet. Another operator working in rough country and using five 12 by 12 inch yarding engines stated that the fuel oil consumed averaged about 6 barrels per engine per yarding day. In another case four yarding engines, working a total of 533 machine days, consumed fuel oil at the rate of 7.8 barrels per engine per yarding day the first year oil was used as fuel. The next year with experience and after various changes had been made in the engines—such as doing away with the blowers and increasing the height of the stacks—the oil consumed averaged 6.1 barrels per engine per yarding day.

The following is a more or less detailed record of the oil consumed in three yarding engines:

(a) Logging engines, 11 by 13 inch; boiler, 66 by 120 inch, 200-pound working pressure, safety valve set at 185 pounds; time, 5 months; average daily consumption, 9.6 barrels; chance, rough ground; average log, 1,975 feet; maximum yarding distance, 1,300 feet; average yarding distance, 650 feet; average output per engine per yarding day, 80,500 feet. Cost of fuel oil per barrel delivered in tank on rear end of sled, \$1.05, or \$0.137 per thousand feet. It is estimated that had wood been used the fuel cost would have amounted to \$0.225 per thousand feet, so that the burning of oil resulted in a saving of \$0.088 per thousand feet.

(b) Logging engine, 11 by 13 inch; boiler, 66 by 120 inch, 200-pound working pressure, safety valve set at 175 pounds; time, 5 months; average daily consumption, 7.8 barrels; chance, ground was extremely rough, requiring at times the use of two lead blocks and a stump roller; average log, 1,870 feet; maximum yarding distance, 1,500 feet; average yarding distance, 750 feet; average output per engine per yarding day, 59,400 feet. Cost of fuel oil per barrel delivered in tank on rear end of sled, \$1.05, or \$0.138 per thousand feet. It is estimated that had wood been used the fuel cost would have amounted to \$0.305 per thousand feet, so that \$0.167 per thousand feet was saved by burning oil.

(c) Logging engine, 11 by 13 inch; boiler, 66 by 120 inch, 200-pound working pressure, safety valve set at 185 pounds; time, 29½ days; average daily consumption, 8.9 barrels; chance, up-hill yarding, the maximum lift amounting to 325 feet; maximum yarding distance, 1,200 feet; average yarding distance, 609 feet; average output, 98,700 feet. Cost of oil per barrel delivered in tank on rear end of sled, \$1.05 per barrel, or \$0.089 per thousand feet. It is estimated that had wood been used not more than 75,000 feet per day could have been yarded and the fuel cost would have amounted to \$0.184 per thousand feet, so that \$0.095 per thousand feet was saved by burning oil.

Those who have used coal in their logging engines feel that it has a decided advantage over wood. It does not, however, decrease the fire risk, neither is it a cheaper fuel than oil; so oil is preferred to coal, except in special cases where coal can be bought very cheaply.

The cost statements of operators do not show the cost of fuel consumed in logging engines as a separate item, and where wood is used the value of the merchantable timber consumed in this way is not charged against the cost of the logging. Since purchasers of national forest timber pay the same prices for merchantable timber consumed as fuel as for timber removed from the sale area, it is obvious that the cost of such material should be provided for in timber appraisals. Of course, if the character of the timber is such that it is clear that ample and satisfactory fuel can be secured from cull logs, the appraising officer will not make any allowance in his estimate. While it costs as much, or more, to deliver a wood log as a merchantable log alongside the logging engine, it may not be practicable for an appraising officer to take care of this cost under the heading "Fuel cost," since it can more easily be provided for in the estimated yarding output. The labor cost of preparing the wood for fuel can also be more easily taken care of under the heading "Yarding cost, labor."

The amount of sound wood consumed in a yarding engine ranges from 1,000 to 1,500 feet per day, depending for the most part on the

size of the engine, the character of the country, and the amount of work done. Under ordinary conditions the amount consumed comes to about 20 feet per thousand feet of output. Figuring stumpage at \$1.50 per thousand feet, the fuel cost of wood per thousand feet of output amounts to \$0.03; stumpage at \$2 per thousand feet, \$0.04; stumpage at \$2.50 per thousand feet, \$0.05; stumpage at \$3 per thousand feet, \$0.06.

The amount of fuel oil consumed in a yarding engine ranges from 6 to 8 barrels per day. Under ordinary conditions the amount consumed amounts to about 5 gallons per thousand feet of output. On this basis, with the delivery cost of oil at \$1 per barrel, the fuel cost of oil per thousand feet amounts to \$0.12; with the delivery cost at \$1.10 per barrel, \$0.132; with the delivery cost at \$1.20 per barrel, \$0.144; with the delivery cost at \$1.30 per barrel, \$0.156.

A yarding engine consumes about $1\frac{1}{2}$ tons of coal per day. On this basis, with a delivery cost of coal at \$4.50 per ton, the cost of fuel per thousand feet amounts to about \$0.135.

Lubricants, waste, and packing.—Few companies segregate the cost of lubricants, waste, and packing, and possibly no operator is in a position to say confidently what their cost amounts to per thousand feet yarded. The amount is small, about \$0.01 per thousand feet. The fixed investment in the supplies is about \$50 per yarding engine.

Maintenance of yarding engines.—Regardless of the care given ground engines, there will be breakdowns through wear, latent defects, or accidents. It is impossible to do more than approximate the maintenance cost per year on this class of equipment.

Seldom is the total cost of repairs on yarding engines, consisting in a general way of shop and miscellaneous labor, new parts, and repair materials, etc., segregated in such a way as to enable one to speak confidently of it. Besides, the maintenance cost varies with the size of the timber, character of ground, stability of sled. kind of settings, the speed at which the machines are driven, etc.

At one camp the cost of repairs on three yarding engines for one year amounted to \$1,836, or \$612 per engine. During the year some improvements were made on the engines, the cost of which is included in the above figures. The engines handled about 27,000,000 feet of timber. At another camp the repairs on two yarding engines for one year cost \$422, or \$211 per engine. The engines handled about 18,000,000 feet of timber. A year's upkeep of another yarding engine which handled 11,000,000 feet of timber amounted to \$682. The year's repairs on two other yarding engines which handled 21,000,000 feet of timber averaged \$357 per engine. A year's repairs on a yarding engine that handled 9,000,000 feet of timber amounted to \$180. The above figures represent total costs, including labor, repair parts, material, etc.

Repair parts, materials, etc., other than labor, and iron and steel bars, for three $10\frac{1}{2}$ by $10\frac{1}{4}$ inch, compound-gear engines for six months cost \$216, or \$72 per engine. This is at the rate of \$150 per engine per year. The engines were about 3 years old, working in better than average ground, and receiving good care. The repair parts, materials, etc., for six yarding engines for one year amounted to \$1,200, which is at the rate of \$200 per engine per year. The engines were about 5 years old and worked hard.

The total cost of taking out old flues and putting new ones in a yarding engine amounts to about \$420, as follows:

Cost of 282 flues.....	\$282. 00
Cost of freight.....	6. 00
Cost of 5 men for 7 days.....	134. 00
	422. 00

The cost of putting in a main-drum shaft amounts to about \$244, as follows:

Cost of labor.....	\$106. 00
Cost of new shaft.....	131. 00
Cost of freight.....	7. 00
	244. 00

Appraisers of National Forest timber estimate the annual cost of the upkeep of yarding engines at from 8 to 10 per cent of their original cost, the amount being equally divided between labor and material.

Depreciation on yarding engines.—No class of equipment is called upon for such extremely severe service as ground yarding engines. The demands made upon them are frequently far beyond their normal capacity. In addition, it is difficult to give them the attention they should have to keep them in good running order. This results in a relatively short life.

It is not possible to more than approximate the life of the ground yarding engines which are now being manufactured. There are several reasons why this is true:

(1) Ground yarding engines have undergone many changes, and those on the market are stronger than those built even a few years ago. The only basis for estimating the life of the present-day engine is the length of service secured from engines that have been or should have been discarded, taking into consideration the period of efficient service and the question of obsolescence. There are yarding engines working in camps that are 12 or 14 years of age. It may be, however, that it would be profitable to replace them with new engines; that the increased cost of logging, because of obsolescence and high maintenance costs, more than offsets the effect of a lower depreciation charge and a lower fixed investment.

(2) The life of yarding engines is frequently shortened through working them far beyond their efficient capacity, also through insufficient maintenance.

(3) It is frequently prolonged through unprofitable care.

(4) The industry has not kept cost records in such form as to enable one in a given case to say confidently when the efficient life has been passed.

Most operators place the efficient life of ground yarding engines at eight years. One of the leading operators of the region figures that it is economical to work his yarding engines hard for four years, sell them, and buy new ones. Possibly he works them harder than any other operator. If he can sell his engines at the end of four years for one-half of their original cost, which he hopes to do, it would seem that he figures on a life of about eight years.

For the purpose of arriving at the amount that should be written off annually for depreciation on this class of equipment, in connection with the appraisal of national forest timber, the efficient life of yarding engines has been placed at eight years, with a scrap value of 10 per cent of the original cost.

ESTIMATING THE COST OF YARDING.

The following hypothetical statement will serve to summarize the several items of expense in yarding and to show an estimated cost of yarding per thousand feet on the basis of an output of 60,000 feet per day per engine. It will also serve as a guide in estimating the total cost of yarding, including labor, supplies, repair parts and material, maintenance, depreciation, and supervision.

TABLE 20.—*Estimated total cost of ground yarding.*

Items.	Total daily cost.	Cost per 1,000 feet.
Labor cost.....	\$39.60	\$0.66
Wire rope.....		.136
Rigging.....		.03
Blocks, hooks, and rollers.....		.02
Fuel oil.....		.132
Lubricants, waste, and packing.....		.01
Depreciation on logging engine.....		.06
Maintenance of logging engine.....		.04
Woods water system.....		.02
Foreman, scaler, timekeeper, and bookkeeper.....		.04
Total.....		1.148

The labor cost is based on an average daily output of 60,000 feet, which takes into account both productive and unproductive time. It is assumed that no extra yarding engine is used, which means that the regular yarding crew moves the engine from one setting to another.

The crew, wages, and total daily labor cost are shown in the following statement:

	Unit.	Total.
1 hook tender-----	\$6. 00	\$6. 00
2 rigging slingers-----	3. 60	7. 20
2 choker men-----	3. 50	7. 00
1 chaser-----	3. 40	3. 40
1 swamper-----	3. 25	3. 25
1 sniper-----	3. 25	3. 25
1 signalman-----	3. 00	3. 00
1 engineer-----	3. 75	3. 75
1 fireman-----	2. 75	2. 75
		39. 60

The wire-rope cost per thousand feet is based on the following assumptions: (1) The main line is $1\frac{1}{4}$ inches in diameter and 1,200 feet long; the trip line, five-eighths inch in diameter and 2,500 feet long; the straw line, three-eighths inch in diameter and 2,500 feet long; (2) that the main line will handle 4,000,000 feet of timber; the trip line, 8,000,000 feet; and the straw line, 25,000,000 feet; (3) that the selling price of wire rope is 50 per cent off the list price, and that the freight on a set of lines amounts to \$13.35.

The rigging cost per thousand feet includes chockers, tag, and yarding lines, straps, etc.

The cost of fuel oil is based on the assumption that 5.04 gallons of oil will be burned per thousand feet of output and that the delivery price of oil is \$1.10 per barrel (42 gallons).

The depreciation on the yarding engine includes the depreciation on a standard 12 by 12 inch, compound-gearred yarding engine valued at \$4,725, an extended fire box, fair-leaders, water tank, and yarding engine sled. It was assumed that the efficient life of the logging engine is eight years, with a scrap value of 10 per cent of the original cost. It was further assumed that the equipment would be used 25 days per month and 8 months per year, or to handle 12,000,000 feet per year.

The maintenance of the yarding engine includes the cost of the labor and repair parts and materials for the up-keep of a standard 12 by 12 inch, compound-gearred yarding engine, together with an extended fire box, water tank, straw-line drum, and fair-leaders.

One month of the salaries of the foreman, scaler, timekeeper, and bookkeeper is charged against the side.

HIGH-LEAD YARDING.

High-lead yarding involves no great modification of ground yarding; the lead block is simply attached to a spar tree as high as practical from the ground instead of to a stump, so that the hauling line tends to lift the front end of the log from the ground. The introduc-

tion of high-lead yarding on a considerable scale is very recent, but has grown in popularity. It appears, in fact, to have followed the success of the overhead system, which does away with the necessity of constructing landings and has demonstrated advantages in log transportation.

High-lead yarding has been employed in the East for many years. A number of operators on the Pacific coast have no doubt used this system in a modified form at different times for short periods for several years. As early as 1906 a logging company in British Columbia used a high-lead system of the type used in the East; that is, with the yarding and loading engine mounted on a swivel-truck car. This installation was not immediately followed up by others. About 1912 another logging company in British Columbia started to use a high-lead yarding system that resembled those in use at present. It seems that the company's major reason for trying the system was to get away from the construction of landings. They found that the system, in addition to obviating the necessity of using landings, increased their yarding output. In 1916 a large number of operators were using the high-lead yarding system, and it looks as though it would supersede the ground system to a great extent.

The chief advantage of the high-lead system over the ground system is that there is a lift to the logs as they come in, so that they are not stopped so much by stumps and other obstructions, and travel faster. This advantage is greater the higher the lead block is fixed, but is lost in practice when the yarding distance exceeds 500 to 600 feet. Within these limits the front end of the log is elevated sufficiently to prevent nosing in soft ground and to provide free movement past stumps and windfalls. In working across canyons the high lead reduces the time lost through logs nosing into the bottom of the canyon or plowing into the opposite slope. Another advantage is that the landing place is kept relatively free of chunks, tops, and other trash, a source of trouble and expense with the ground system. It has been indicated that the high-lead system does not require landings, the resultant saving just about offsetting the extra expense of preparing the spar tree and swinging the lead block. In addition, yarding may proceed more constantly because the logs delivered at the landing place may be piled one on top of the other for some time, regardless of whether loading is going on or not.

When hauling down a steep slope the high-lead system probably is not so satisfactory as the ground system. In the case of side-hill work the logs have the same tendency to roll behind obstructions. It must be borne in mind also that much of the timber now being logged does not afford trees high and stiff enough for spar trees, and that it is expensive to maintain a rigging crew in some camps.

METHOD.

The method of high-lead yarding is illustrated by figure 34. A suitable tree conveniently located near the track is used as a spar tree. This tree, with the top cut off at from 120 to 200 feet from the ground, is guyed with from six to nine lines to give it rigidity. In the case of high spar trees there are usually six guys from the top and three from a point near the middle. If a double-line system of loading is used, two additional guys are necessary. A high-lead block, with a sheave from 24 to 36 inches in diameter, is hung near

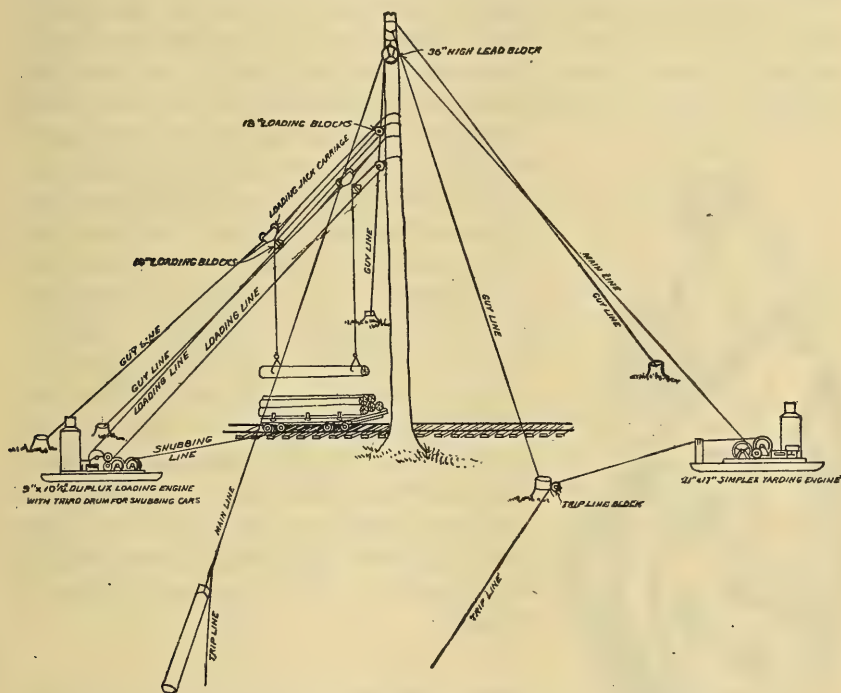


FIG. 34.—Location of equipment and improvements in high-lead yarding.

the top of the spar tree below the guy-line fastenings. The hauling line is passed from the drum of the engine to and through this block, and on and out to the logs to be yarded, the power being furnished by the trip line, as in the case of ground yarding. As a rule, no landings are built; but, owing to the large output secured, a loading engine in addition to the yarding engine is necessary in all cases. The yarding engine may be set at the base of the tree, or from 150 to 250 feet from it. In some cases the yarding and loading engines are mounted on an ordinary flat car or a special steel car with swivel trucks. (See guy-line loading under "Loading.")

One company has found that the base of the spar tree should be from 14 to 20 feet from the center of the track. To insure the workmen against injury certain precautions are taken. The main-line lead block is hung in a 2-inch strap, the pins and shackles of these blocks being extra large. A "safety" guy is rigged under the bight of the main line in such a way that the main line will be deflected in case any of the rigging breaks. The bark on the spar tree is removed for several feet at the point where the lead block strap is attached, thus preventing it from being dislodged when yarding is in progress.

The general method of using a saw or ax to cut off the tops of trees selected for spars is both tedious and dangerous work. One company is using dynamite instead. The head rigger puts on a pair of long-spurred climbing irons and ascends the tree to the desired height, taking several sticks of dynamite with him. The dynamite, which is tied together end to end, like a string of sausages, is fastened securely around the tree at the point where he desires to remove the top. A detonating cap, to which a long piece of fuse is attached, is inserted in one of the sticks of dynamite. The rigger descends 20 feet or so, lights the fuse, and makes his way to a safe place on the ground some distance from the tree. After a few minutes the dynamite explodes, the tree top leaps into the air and comes crashing down. This way of removing the tops is only in the experimental stage at present.

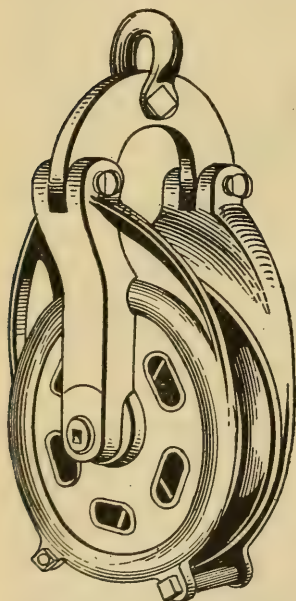


FIG. 35.—Auto-lubricating high-lead block.

EQUIPMENT.

The equipment used in high-lead yarding differs little from that used in ground yarding.

Yarding engines.—Any kind of two-drum yarding engines may be used. To take full advantage of the system, however, an engine with higher drum speeds than that of standard yarding engines should be used. One company, working on good ground and in second-growth timber where the logs average about 600 feet in volume, has purchased yarding engines designed especially for this system. These machines are simple geared, with 11 by 17 inch cylinders. Both main and trip drums are driven directly from pinions on the crank shaft without the interposition of counter shafts or idlers. The drums are narrow and of large capacity. The increased length of stroke compensates

for the gear ratio involved in abolishing compound gearing. This type of yarder is also manufactured with 13 by 18 inch cylinder. The 11 by 17 inch engines cost about \$5,500 and weigh about 55,000 pounds. Steel cars cost about \$2,000; when they are equipped with air brakes, \$2,200.

Lines and chokers.—Lines and chokers are of the same grade and construction as those used with the ground yarding system. The lines in both systems are of practically the same length, since the distances yarded are about the same. The main yarding line of the ground system is, of course, a little longer than that of the high-lead system. It is claimed that it is practicable to use lines of a little smaller diameter with the high lead than with the ground yarding system.

High-lead blocks.—While the desirability of a large lead block is clear, opinions differ as to the proper size. The sheaves of those in use range from 24 to 36 inches. One operator has found the smaller block satisfactory. There are several makes of high-lead blocks on the market. Figure 35 shows one of the autolubricating types. An ordinary butt-chain lead block was first used as a high-lead block, and some operators are still using the butt-chain lead block for this purpose. The size, weight, and net selling price of three sizes of autolubricating high-lead blocks are as follows:

TABLE 21.—*High-lead blocks.*

Number.	Size of sheaves.	Bearing.	Diameter of pin.	Oil capacity.	Weight.	Net selling price.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Gallons.</i>	<i>Pounds.</i>	
1.....	24 by 5.....	7	3½	1½	485	\$104
2.....	30 by 5.....	7	3½	1½	835	149
3.....	36 by 5.....	10	3½	2	970	167

EXTRA PARTS.

Items.	No. 1.	No. 2.	No. 3.
Tool steel shackle with clevis complete.....	\$18.90	\$21.00	\$22.50
Shackle clevis and pin.....	6.75	6.75	6.75
Shackle pin with automatic lock.....	2.00	2.00	2.00
Pair steel block sides.....	38.00	67.00	72.00
Hardened steel pin.....	6.00	8.00	8.00
Bronze bushing.....	7.00	11.70	11.70
Manganese steel sheave, bronze bushed.....	47.25	67.00	77.00

The high-lead block is hung from 6 to 12 feet below the point where the guy cables are attached to the spar trees with a 1½ to 2 inch plow steel strap, wrapped either once or twice around the spar tree. As a matter of safety an additional strap is placed through the yoke of the block and loosely around the spar or one of the guy lines.

This second strap is intended to hold or slide the lead block slowly to the ground in the event the main strap breaks.

Trip-line blocks are the same as those used with the ground yarding system.

COST.

The high-lead method is the cheapest method of yarding under certain conditions. It has displaced the ground yarding system in many cases, and the overhead system in a few. It seems assured of a permanent field, but just how large can not be said at this writing.

Labor cost.—Yarding output, which, with all yarding systems, largely determines the labor cost, under proper conditions is from 15 to 30 per cent higher with the high lead than with the ground system.

The high-lead yarding crew is practically the same size as the ground yarding crew. A sniper is not necessary with the high-lead system, and the amount of powder used for clearing out yarding roads is negligible when compared with that used in connection with the ground yarding system. And, roughly, the same wages are paid. Under the same conditions, the total labor cost per day, aside from the labor cost for preparing spar trees, is practically the same with both systems.

The crew at one operation where the high-lead system was used in connection with practically level land and second-growth timber was as follows:

- 1 hooktender.
- 2 rigging men.
- 3 choker men or hook-on men.
- 1 swamper.
- 1 signalman.
- 1 chaser.
- 1 engineer.
- 2 wood buckers.

The guy-line system of loading (see the discussion of guy-line under "Loading") with one loading line was used. The yarding and loading engines were mounted on a flat car set on a siding at the base of the spar tree, steam for the loading engine being furnished by the yarding engine boiler. The loading engine or lever man was paid \$5 per day. The chaser unhooked the logs when they were yarded to the landing place and hooked the logs when loading was in progress. In most cases the chaser has all he can do to unhook the logs and another man is needed to hook the logs in loading. There are times, of course, when the chaser can help with the loading. This time is by no means lost, since not infrequently the loading operation holds up the yarding, the help of the chaser tending to relieve this condition.

The company was averaging about 90,000 feet per yarder per yarding day with the high-lead system as against 60,000 feet with the ground-yarding system.

Two riggers were employed in the preparation of spar trees for two sides, the work taking about two-thirds of their time. In September, 1915, these men were paid as follows: Head rigger, \$4 per day; second rigger, \$3.50.

Another operator, working in large timber, has found that the labor cost for rigging a standing tree for a spar amounts to from \$75 to \$100. This includes the moving and setting of the loading engine and the taking down, bucking, and loading of spar trees that are not to be used again. Where the spar tree has to be raised—and this frequently has to be done to get the lead block in proper position for yarding—the labor cost for rigging runs from \$100 to \$200. In July, 1916, the riggers were paid as follows: Head rigger, \$6 per day; second rigger, \$4.

Inasmuch as spar trees take the place of two landings occurring on opposite sides of the track, the cost of spar trees in this case was about equal to the cost of the landings that were used with the ground-yarding system.

Other items of cost.—The cost of other items per thousand feet is a little less with this system than with the ground-yarding system. There are no landings to be built, which in one of the cases referred to above meant a saving of about \$0.10 per thousand feet. One spar tree being used to yard on both sides of the track, the number of yarding engine moves is reduced. It does not take so long to change ends. The cost of the yarding lines is a little less, possibly 25 per cent. The cost of fuel and other supplies, the maintenance of equipment, as well as the amount written off for depreciation, is about the same with both systems.

OVERHEAD YARDING.

With the passing of the timber from the lower lands, logging operators in the region are confronted with the problem of handling logs—in many cases smaller logs—on rougher and steeper ground and over greater distances from the spur railroads. To do this work at the cost of past logging or less another method was necessary. Resort is being made, therefore, to an overhead or tight-line system.

While overhead logging methods have been employed for many years in the east, it is only within the last few years that they have been used to any extent by loggers of the Pacific Northwest. During a relatively short period they have reached the stage of dependable rigs, the output of which can be predicted with some degree of cer-

tainty, and the results secured so far give distinct promise of further improvement.

One operator has come to certain tentative conclusions with regard to the use and adaptability of overhead systems in coast timber, which may be summarized as follows:

(a) That overhead systems have little advantage over ground yarding systems in level or slightly sloping country and that they are not so satisfactory as the high-lead system on short hauls.

(b) That overhead logging can be successfully and economically employed on almost any kind of ground, provided the quantity of timber justifies the necessary expenditure for proper equipment. Some rough mountain sides have been logged from railroads at their base, and numerous other types of rough country have been logged at moderate expense that could not have been logged at all with other systems, practically considered.

(c) That the length of overhead line which can be successfully employed depends on the support which can be given the line, the weight of the load to be carried, the size of the line, the grade of the line in operation, and the deflection of the line. Wire rope is constructed to withstand certain pulls and stresses. The stress or tension on a cable suspended between two points is entirely different from that of any other type of rope application, and as a rule much greater than the stress expended by the suspended load. Too often conditions necessitate the use of an overhead cable with little sag or center deflection, and sag governs in a large measure the length of the cable. Putting it another way, the greater the deflection that can be secured the longer the cable that can be used.

(d) That machinery designed and built for ground logging is not adapted for overhead logging. Ground logging machinery is built for power and to withstand strains. Furthermore, there is no elasticity in its make-up. Under certain stresses the engine or the line may break. Overhead logging engines, on the other hand, should have high-speed drums and be so constructed as to refuse to handle any load in excess of that allowed by the factor of safety in the overhead line. Under certain conditions excessive strains on the overhead cable can be prevented by the arrangement of the other lines. Engines adapted for both ground yarding and overhead or high-lead yarding can now be purchased. These have two speeds—one for ground yarding, the other for overhead or high-lead yarding. The slow-speed pinion can be shifted in one-half hour's time, the result being that a high-speed engine adapted for overhead logging is converted into a slow-speed engine for ground yarding.

The bases of these conclusions are to be found in the peculiarities of the system. A wire hung between two supports along which the

log travels suspended from a trolley is the characteristic feature. This arrangement results in both advantages and limitations. The advantages in the main are the reduction of friction and the fact that with a structure that costs very little as compared with a railroad or pole road logs can be yarded for long distances at a uniform speed. The limitations are fixed by the strength of the line as related to its own weight, the tension that has to be applied, and the service required of it. The load imposed by a turn of logs, great as it may be at times, is a small part of the normal burden. The tension necessary to keep it from sagging to the ground is greater on long reaches. That, combined with the weight of the line, in time exhausts its tensile powers.

These considerations, well understood by makers of wire rope and machinery, weighed heavily on the layout of the first attempt with this system. A thousand feet was the longest reach attempted. Trial, however, chiefly inaugurated by loggers under the spur of necessity, has demonstrated the practicability of longer reaches. Difference in elevation of the two cable supports is the key to the matter. This changes the forces on the line greatly, and as much of the ground to be logged compels just this arrangement the method has of late been successfully employed on two or three times the distance originally proposed. Not always, of course, does topography so lend itself. Intervening ridges may cut off the opportunity to stretch a cable for a long distance, or at least prevent the line from taking the sag which safeguards it.

Three methods which are used successfully are described. Two of these require special engines, and the other gives the best results when used in connection with a special engine. It should not be understood, however, that they are the only methods that have been used or that no other types of engines or line arrangements have been thought of. These methods have been used the most, have been given the most publicity, and probably represent the best principles so far evolved. The use of overhead logging methods for swinging or roading is dealt with under "Swinging."

LIDGERWOOD OVERHEAD SYSTEM.

The Lidgerwood overhead system consists of a standing wire cable suspended either between two trees, known as the head spar and the tail trees—the tree-rigged type (fig. 36)—or between a portable steel head spar and a tail tree—the portable spar type. In the tree-rigged type one end of the standing cable passes around the tail tree, being held in place by spikes, or over a tree shoe (fig. 37) suspended on the tail tree, and then down to a stump, to which it is made fast. The other end of this cable may be connected to

a main cable extension (fig. 38) between the spar trees near the head spar by means of a block and fall tackle, the main cable being tightened with the aid of the engine; or the main cable may lead through

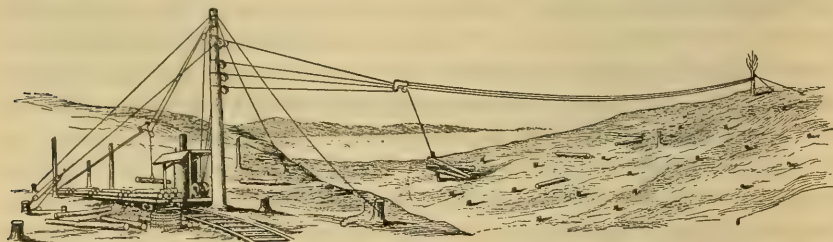


FIG. 36.—Location of equipment and improvements, Lidgerwood overhead system.

a jack on the head spar (fig. 39) and then down to a stump, where it is connected. The latter is generally used in this region. The method of tightening is the same in both cases. The steel-spar type is provided with a steel head spar built upon the skidding car and carried with it. This steel spar carries all the head blocks and rigging, with all the lines reeved and in place.

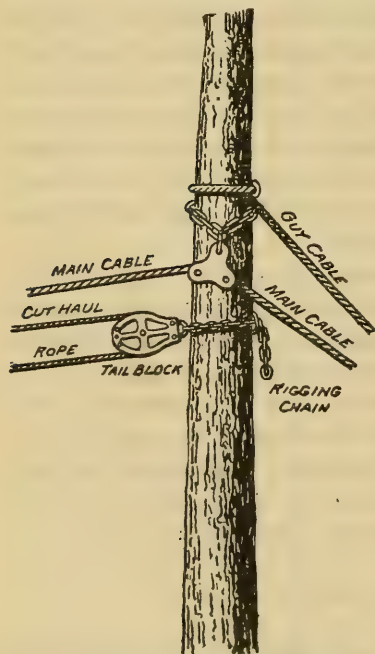


FIG. 37.—Tail tree, Lidgerwood overhead system.

head cable is stationary. An auxiliary engine is used to load the logs.

This system of yarding is a product of the East, having been used for a comparatively long time in the forests of the South and

A slack-pulling skidding or yarding carriage travels on the cable (fig. 40), being moved toward the head spar by the skidding or hauling line and toward the tail tree by the return or trip line. This carriage also carries the slack-pulling line, which enables the engine to give out the length of skidding line necessary to reach the logs lying to one side or the other of the overhead cable. Lines other than the main standing cable lead from their respective drums on the skidding engine through blocks on the head spar, or both the head spar and tail tree, and thence through the skidding carriage to their respective positions. In operation the over-

Southeast. The original machine was invented by Horace V. Butters, of Ludington, Mich., in 1883. It was a crude device, which used manila rope for skidding lines; improvements made from time to time have brought it to its present state of efficiency.

The first Lidgerwood overhead skidder on the Pacific coast was introduced in 1904. It was of the tree-rigged type and was the largest machine of this design built up to that time, having 10 by 12 inch skidding and 9 by 10 inch loading engines. While it did fairly satisfactory work from the beginning, several changes had to be made to adapt it to the new conditions. For the last 10 or 11 years it is said to have done

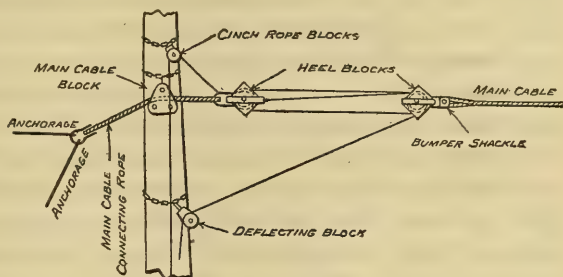


FIG. 38.—Block and fall outfit, Lidgerwood overhead system.

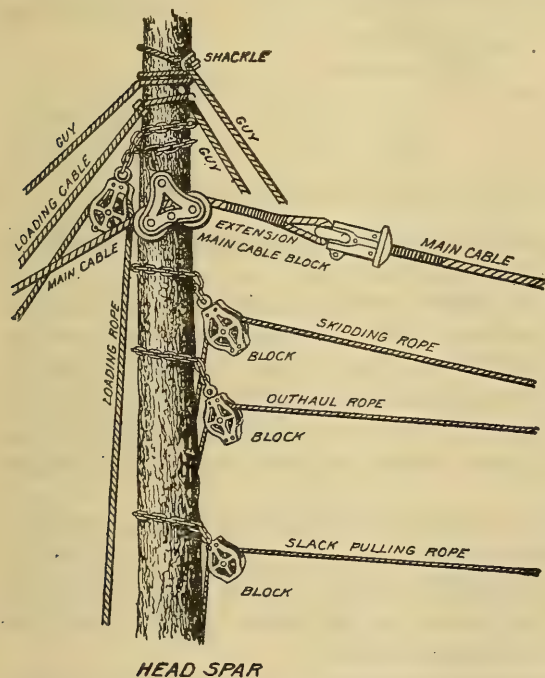


FIG. 39.—Main line extension, Lidgerwood overhead system.

Machines.—The tree-rigged machine of the type that has been installed within the last few years is made up of two sets of double engines, one for skidding and one for loading.

satisfactory work. In 1907 several 12 by 12 inch overhead skidders were installed in the region. The following year a 12 by 12 inch skidder of a heavier type was introduced, and this is the type of machine that is now being used by a number of operators. The manufacturers of the skidder are now building a 13½ by 16 inch tree-rigged machine, which they hope will successfully handle any log required by the conditions in this region. During 1916 at least five coast operators purchased steel-tower skidders.

The main engine, or what is known as the skidding engine, has 12 by 12 inch cylinders and three drums. The back drum, the one next to the boilers, is known as the skidding line drum. This drum hauls the log in. The middle drum is known as the return or trip line drum. This is used not only to haul the carriage back to the woods but to hold the carriage in proper position when the log is being yarded under the carriage, also to regulate the speed of travel of the load when gravity carries it forward. The return line drum is provided with an interlocking and reversing device, which permits the interlocking of the skidder and receding line drum after the ends of the logs have been elevated sufficiently to clear obstructions. By means of this device the return line is paid out automatically as the skidding line is drawn in. The third drum from the boiler is the slack-pulling drum, which enables the engineer to pay out from the carriage the length of skidding line that is necessary to reach the logs that lie to one side or the other of the overhead cable. The slack-

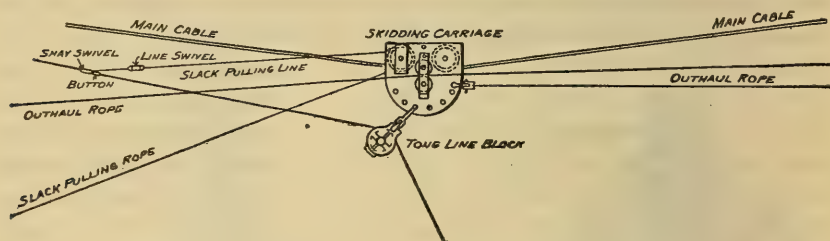


FIG. 40.—Skidding carriage, Lidgerwood overhead system.

pulling drum has a friction device set with a tension of about 500 pounds, so that the line will not hang slack.

The loading engine has double cylinders and four drums, two friction and two clutch drums. The friction drums are used in loading, but only one of them at a time. The two make it possible to shift the loading line from one side to the other, so that it is unnecessary for the loading engineer to look over the machine when loading is in progress. The two clutch drums are used for raising the main cable, rigging, etc.

The machine, as a rule, is mounted on a steel car, which is 22 by 8 feet and is equipped with a jack at each corner and swivel trucks. With this equipment it is possible to jack up the car, turn the trucks, lay short pieces of steel rail under the car wheels at right angles to the track, and move the car from the track.

The skidder may be mounted on a sled; in fact, some operators find it suits their purpose best to mount it this way. No other method could be used where it is necessary to place the skidder at some point other than along the track.

There are in use in the United States seven types of steel spar-skidders, each made in several different sizes. The one designed to handle timber of average size in this region is equipped with 12 by 12 inch, double-cylinder, high-speed engines, with five drums. Then there is the utility engine with 10 by 10 inch cylinders and four drums. On the front of the machine there is a 12 by 12 inch swing-loading-boom loading engine, mounted on a turntable. This engine drives three friction drums. Up in the tower, underneath the steel spar, there is a four-drum, guy-tightening engine. The skidding engine has a hauling-line speed of from 500 to 800 feet per minute, and a return-line speed of from 1,800 to 3,000 feet per minute. The machine is mounted on a steel frame. This frame with its supporting legs is raised or lowered by hydraulic jacks, to allow empty cars to pass beneath it.

The selling prices of the skidder and loading engine f. o. b. Portland or Seattle, exclusive of blocks and lines, were approximately as follows in 1916:

Prices of skidder and loading engine.

TREE-RIGGED TYPE.

(1) 12 by 12 inch skidder, 10 by 10 inch loading engine, mounted on a steel car	\$11,500
(2) 12 by 12 inch skidder, 10 by 12 inch loading engine, mounted on a steel car	12,500
(3) 12 by 12 inch skidder, 12 by 12 inch loading engine, mounted on a steel car	13,000
(4) 12 by 12 inch skidder adapted for mounting on a wooden sled	9,500
(5) 13½ by 16 inch skidder adapted for mounting on a wooden sled	22,000
(6) 12 by 12 inch skidder, 10 by 10 inch loading engine, adapted for mounting on a wooden sled	9,700
(7) 12 by 12 inch skidder, 10 by 12 inch loading engine, adapted for mounting on a wooden sled	10,700
(8) 12 by 12 inch skidder, 12 by 12 inch loading engine, adapted for mounting on a wooden sled	12,500
(9) 13½ by 16 inch skidder, 10 by 10 inch loading engine, mounted on a steel car	23,000
(10) 13½ by 16 inch skidder, 10 by 12 inch loading engine, mounted on a steel car	26,000
(11) 13½ by 16 inch skidder, 12 by 12 inch loading engine, mounted on a steel car	32,000

STEEL-SPAR TYPE.

(1) 12 by 12 inch skidder, 10 by 12 inch loading engine, mounted on a steel car	28,000
(2) 12 by 12 inch skidder, 12 by 12 inch loading engine, mounted on a steel car	32,000

Main cable supports.—In the case of the tree-rigged system trees support the main cable (fig. 36). The head spar, only one of which is required to log an entire setting, may be a tree that, as a result of accident or design, is located at the proper place; or it may be a pole erected there. The head spar is from 100 to 150 feet in height and about 30 inches in diameter at the top. If a tree is used, and such is usually the case, the top is cut off to protect the workers and the machine from falling limbs. The head spar is braced with from six to nine guys attached to the top of the spar or at both the top and middle. The tail trees are selected before felling begins and are left standing, although occasionally a top is cut off to avoid trouble. The tail trees are also guyed.

The distance between the main cable supports (fig. 41) ordinarily ranges from 800 to 1,400 feet, which means that an area of from 40 to 100 acres can be logged at one setting. Logs can be yarded as far as 200 feet behind the tail tree. On steep mountain sides, the skidder

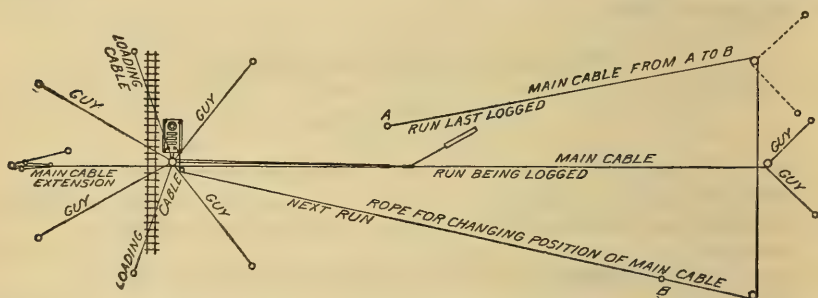


FIG. 41.—Location of roads, Lidgerwood overhead system.

may be rigged to yard logs 2,000 feet or more; in rare cases, up to 3,000 feet.

It is necessary to use a new tail tree with every run. The distance between the runs depends on several factors, such as the character of the ground, size of timber, density of stand, location of suitable tail trees, etc. The tail trees are usually from 150 to 250 feet apart. The closer they are together, the easier it is for the tong men, and the more work it means for the rigging crew. The best results with this system are ordinarily obtained when the skidder is hauling about 1,000 feet and the tail trees are about 150 feet apart.

Operation.—In operation, the return line draws the carriage out along the main cable. When the carriage reaches the place where the logs are to be picked up, the return line drum is thrown out of gear and the foot brake is applied, holding the carriage stationary. The tongs or chokers are then lowered to the ground by drawing in the slack-pulling line. After the slack is pulled, the tongs or chokers are carried out by the tong man, to the log or logs to be hauled and attached. The skidding rope is then drawn in, with the return line

held taut. This keeps the carriage stationary. When the logs are elevated sufficiently at one end to clear obstructions, the skidding and return-line drums are interlocked and the skidding line drawn in (the return line being simultaneously paid out) until the logs are brought to the landing places, where they are dropped ready to be loaded on the cars. The operation of the drum is then reversed and the carriage returned to the woods at high speed by the return line. The operation is then repeated.

Changing lines.—Two main cables are employed. While one is being used in yarding, the rigging crew is at work getting the other in place on the next run. When all the timber on one run has been logged, the main cable is dropped by the lifting and lowering drum and taken out of the carriage. The other main cable, already brought to place by the riggers, is placed in the carriage, connected, and tightened up, the entire change of lines taking from 20 to 40 minutes. The rigging crew then delivers the main cable from the old run to a new one. A light changing or straw line, provided for the purpose, is drawn out by hand from the head spar tree on the new run, up to and around the newly selected tail tree, and thence to the tail tree that has just been deserted. The changing line is there made fast to the main cable left lying on the ground on the run last logged, and then, by means of a drum, drawn back to the head spar tree, thus dragging the main cable entirely around the new tail tree to a position between the head spar and tail tree on the new run, ready to be connected up when required.

Changing settings.—The manufacturers of the skidder state that the change from one setting to another with the tree-rigged type consumes from two to six hours. An operator who is using one of these machines stated that a change from one setting to another could be made in from one-half to three-fourths of a day, provided a double set of rigging is used; that where a single set of rigging is used, the time consumed in changing settings ranges from a day to a day and a quarter.

The loss of time in moving from one setting to another is not considerable when compared with the loss of time in changing the settings of ground yarding engines, since the skidder, as a rule, logs more than twice as large an area at a setting as the ground yarding engine. The skidding roads radiate around the head spar, and the timber on both sides of the track is yarded at one setting of the skidder.

The time consumed in changing settings with the steel-spar type is, of course, considerably smaller, ranging, it is said, from an hour and a half to two hours.

Equipment.—The kind, size, length, and selling price of the lines, also the fixed investment in the lines, are discussed under "Cost."

The number and type of blocks used with this system is indicated in Figures 37, 38, and 39. A complete set of these blocks f. o. b. Portland or Seattle costs from \$1,500 to \$2,000 and weighs from 18,000 to 22,000 pounds.

The type of carriage used is shown in Figure 40. These carriages f. o. b. Portland or Seattle cost from \$400 to \$500 and weigh from 1,000 to 1,200 pounds.

Output.—In general, the output with this system ranges from 50,000 to 100,000 feet per day. For short periods it may be greater or less than this. One skidder, where the maximum yarding distance was 1,000 feet, yarded 1,000,000 feet in five days. On steep mountain sides, where the yarding distance ranges from 2,000 to 2,500 feet, the output may range from 50,000 to 75,000 feet.

The average output per skidder per skidding day, on the basis of a month's time, in a camp where five skidders were used, was 80,000 feet. The largest output of any of these skidders in a day during this period was 182,000 feet. In this camp, during the same month, four ground yarding engines were operated, the average output per engine per yarding day amounting to 40,000 feet. The maximum yarding distance in the case of the skidders was 1,200 feet; in the case of the ground yarding engines, 700 feet. The logs yarded with both systems averaged about 800 feet in volume. Another operator, working a skidder and a ground yarding engine in chances of the same character, was getting about 75,000 feet per day with the skidder and about 40,000 feet with the ground engine. The timber was small, second growth, and the ground practically level. Still another operator was getting an output of about 90,000 feet per day with a skidder. The maximum yarding distance was 1,200 feet, the ground was practically level, and the logs averaged about 1,000 feet in volume. One operator who used the overhead skidder discussed the output as follows:

As to the output, we are not in a position to say what the system will do in a good chance. We have used it in very rough, steep ground and in small timber. From May 1 to May 1 we worked 227½ days, being shut down during the month of July and having the usual Christmas shut down, and put in 9,164,000 feet, or a daily average of a little over 40,000 feet. This is not a large average, but, owing to the conditions, think it is better than we could have done with the ground yarding system. Our largest day was 84,000 feet and our best monthly average was 53,000 feet per day. In these averages the time consumed in moving has been counted in as working days.

Cost.—Nothing further than a general discussion of the elements of cost will be attempted. The factor of output, which has already been referred to, is of major importance. While the size of the crew

used, with this or any overhead system of yarding is much the same as in the case of a ground system, there is some difference in the character of the work performed and the wages paid some members of the crew.

The crew used for skidding, loading, and rigging generally consists of from 16 to 18 men, made up as follows:

Skidding crew:

- 1 skidding engineer.
- 1 fireman.
- 1 wood buck.
- 1 hook tender.
- 2 or 3 choker men.
- 1 unhooker.
- 1 signalman.

Rigging crew:

- 1 head rigger.
- 3 assistant riggers.

Loading crew:

- 1 loading engineer.
- 3 loaders.

This crew is used in connection with a wood-burning skidder. If oil or coal is burned, a wood buck is not necessary. Sometimes five riggers are necessary. A knotter should be added to this crew, unless knotting is considered a part of the operation of felling and bucking.

The fireman, wood buck, hook tender, choker men, and signalman are paid approximately the same wages as in the case of the ground yarding system. For a discussion of the wages paid the loading engineer and loader, see the section headed "Loading." A skidding engineer, as a rule, is paid more than a ground yarding engineer, the wages of the former ranging from \$4 to \$5 per day. A head rigger is paid from \$5 to \$6 per day; the assistant riggers about the same as the choker men.

It is roughly estimated that a crew handling 40,000 feet per day costs about \$50 per day; one handling 60,000 feet per day, about \$55 per day; one handling 70,000 feet per day, about \$60 per day; one handling 80,000 feet, about \$63 per day; one handling 90,000 feet per day, about \$66 per day; and one handling 100,000 feet per day, about \$66 per day.

One crew, handling about 80,000 feet per day in large, second-growth timber on rolling ground, cost about \$63 per day, as follows:

1 skidding engineer	\$4.50
1 fireman	2.75
1 wood buck	2.75
1 hook tender	6.00
1 choker man	3.50
2 choker men, at \$3.25	6.50
1 unhooker	3.50

1 signalman.....	\$ 2.75
1 head rigger.....	5.50
1 second rigger.....	3.50
2 assistant riggers, at \$3.....	6.00
1 loading engineer.....	5.00
1 head loader.....	4.50
1 assistant loader.....	3.50
1 assistant loader.....	3.25
Total	63.40

The labor cost per thousand feet on the basis of the above estimated total daily labor costs is approximately as follows:

Labor cost per thousand feet.

Output per day:

40,000 feet.....	\$1.25
50,000 feet.....	1.00
60,000 feet.....	.90
70,000 feet.....	.85
80,000 feet.....	.79
90,000 feet.....	.73
100,000 feet.....	.66

The cost of the maintenance or replacement of the lines depends, in the main, on the length of the span and the conditions under which the lines are used. The main standing lines in use have either hemp or wire centers, with a tendency toward the latter as their length is increased, and range from $1\frac{1}{4}$ to $1\frac{3}{4}$ inches, or even larger, in diameter. The other lines are of the usual kind. The skidding lines are made of either $\frac{7}{8}$ or 1 inch rope. The approximate size of the other lines used is given in the following table. The length of the lines employed in any given case varies of necessity with the length of the span. This may range from 700 feet on level ground, where the cost of constructing railroads is low, to 2,500 or 3,000 feet on mountain sides where the construction of railroads is practically out of the question. In Table 22 the estimated cost of lines per thousand feet of timber is shown for spans of three different lengths, the lines being the same size in each case. It will be noted that the estimated life of each line in million-foot units is given. The estimated life of each line is approximately correct in most cases, with the exception of the standing line, which can not be safely estimated. The output given for the main cable is too high for some cases and too low for others. Both hemp and wire-center rope are used for main cables, other lines being made of hemp-center rope. The main cables included in the estimates are made of wire-center rope. The price of wire rope is given under "Ground yarding."

TABLE 22.—*Estimated cost of lines, per thousand feet of timber, with the overhead skidder.*

Type of line.	Diameter.	Life in million feet.	Net price per foot.	Case 1 (900-foot span).			Case 2 (1,200-foot span).			Case 3 (1,500-foot span).		
				Length.	Total cost.	Cost per M feet.	Length.	Total cost.	Cost per M feet.	Length.	Total cost.	Cost per M feet.
	<i>Inch.</i>			<i>Feet.</i>			<i>Feet.</i>			<i>Feet.</i>		
1 main cable.....	1 1/2	15	\$0.50	1,300	\$650	\$0.043	1,600	\$800	\$0.053	1,900	\$950	\$0.063
1 skidding line.....	1 1/2	10	.25	1,100	275	.027	1,400	350	.035	1,700	425	.045
1 return line.....	1 1/2	10	.20	2,100	420	.021	2,600	520	.026	3,200	640	.032
1 slack pulling line.....	1 1/2	20	.11	1,100	121	.012	1,400	154	.015	1,700	187	.019
1 straw line.....	1 1/2	20	.09	2,100	189	.01	2,600	234	.012	3,200	288	.014
1 tightening line.....	1 1/2	10	.20	800	160	.016	800	160	.016	800	160	.016
Loading guys.....	3/8	30	.50	800	400	.014	800	400	.014	800	400	.014
Loading line.....	3/8	3	.20	250	50	.016	250	50	.016	250	50	.016
Guy lines.....	3/8		.20	2,200	440		2,200	440		2,200	440	
1 main cable (extra).....	1 1/2		.50	1,300	650		1,600	800		1,900	950	
Total.....					3,355	.159		3,908	.187		4,490	.2.9

Both chokers and tongs are used to attach the logs to the skidding line. In some cases tongs furnish the sole attachment; in others, chokers. Both forms of attachment are sometimes used. Where only one tong is used it is attached to a ring on the end of the skidding line. Where more than one tong is used they are attached to the butt lines or chains, and the butt lines are attached to a ring on the end of the skidding line. Where chokers are used they are attached directly to the end of the skidding line, no butt chains being used. Sometimes one tong and one or more chokers are used, the tong being attached directly to the end of the skidding line.

The cost of chokers and butt lines per thousand feet does not amount to as much as in ground yarding (see discussion of rigging, cost under "Ground yarding"), probably ranging from 1 to 3 cents.

The cost of the replacement and maintenance of blocks, carriage, etc., no one is in a position to discuss confidently. The amount per thousand feet is small, ranging from 1 to 3 cents.

It is conservative to say that the cost of the fuel used in yarding and loading with this system, when the steam for the skidding and loading engine is supplied by a common boiler, is just about equal to the cost of the fuel used in yarding with a ground system.

The cost per thousand feet for lubricants, waste, and packing used in skidding and loading with this system ranges from 1 to 2 cents. (See "Ground yarding.")

The cost of the upkeep of the skidder ranges from \$30 to \$40 per month. (See discussion of the maintenance cost of ground yarding engines under "Ground yarding.")

The manufacturers of this machine estimate its efficient life at 20 years. It may be that with proper maintenance this figure is not too high. However, it is no doubt too high to be used by a going concern or timber appraisers, at least in most cases. The factor of

obsolescence, also the time the skidder can be used by an operator before it has to be disposed of, have a direct bearing on the amount that should be written off annually for depreciation. Conservatively, for the purpose of timber appraisal, the efficient life of a skidder should be placed at 10 years, with a scrap value of 10 per cent of the original cost. (See discussion of depreciation on ground yarding engines.)

MACFARLANE SKY-LINE SYSTEM.

The MacFarlane sky-line system differs from the Lidgerwood system in that no slack-pulling line is employed, the main cable upon which the carriage travels being raised or lowered when the system is in operation. The first step in the evolution of this system was taken in 1905. In that year Mr. C. E. MacFarlane was confronted with the problem of moving logs about 900 feet down a steep slope to the Kalama River, the elevation of the bench above the river amounting to 600 feet, with the slope in places so steep that it was difficult for a man to climb up. To move the logs down this slope on the ground was not practicable and there was not enough water in the river to permit the use of a chute. It was decided that some inexpensive overhead method would have to be used. The trip drum of an ordinary $8\frac{1}{2}$ by 10 inch ground yarding engine, set at the top of the slope, was fitted with a double brake. A 1-inch plow steel cable was made fast to a stump on the opposite side of the river, led up the hill, and passed through a block suspended to a properly guyed tree about 60 feet from the ground. A $\frac{7}{8}$ -inch line ran from the main drum, through a block attached to the end of the main or overhead cable, and thence back around a stump, thus providing a purchase for raising the main cable. A five-eighths-inch trip line was strung about 150 feet to one side of the overhead cable and led through a block to the carriage.

In yarding a log, say, 150 feet from the main cable, the trip line pulled the carriage and main line over to the log, permitting the log to be hooked on; slack was then taken out of the main cable, thus elevating the log, by reeling in the $\frac{7}{8}$ -inch purchase line on the main drum, and the log was lowered down the hill by letting out the trip line. When the log reached the river the main cable was lowered, permitting the load to be unhooked. The device constituted an overhead snubbing system, since it relied on gravity to pull the logs in.

The cost of yarding logs by this system was considerably less than it would have been if a ground-yarding method had been used, the operator finding that the steep ground was logged as cheaply as some moderately level ground with the ground method. The logs ranged from 600 to 1,500 feet in volume.

Five men made up the yarding crew—an engineer, fireman, hook-tender, rigging slinger, and unhooker.

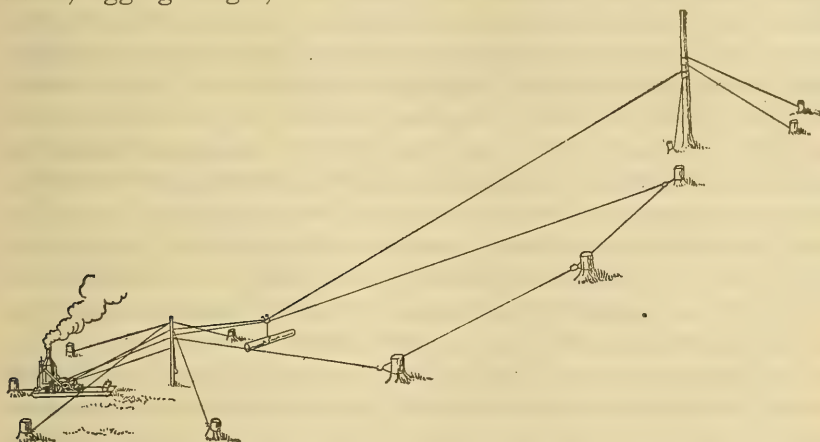


FIG. 42.—Location of equipment and improvements, MacFarlane sky-line system.

The Lidgerwood overhead system has been dealt with in considerable detail, so that only the points wherein the MacFarlane sky-

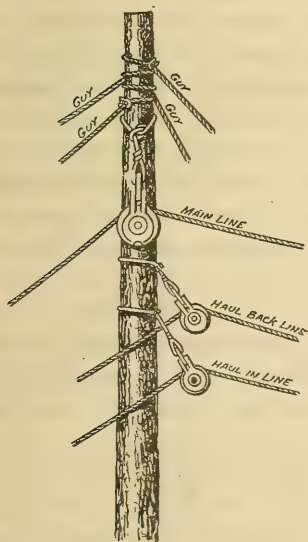


FIG. 43.—Head tree, MacFarlane system.

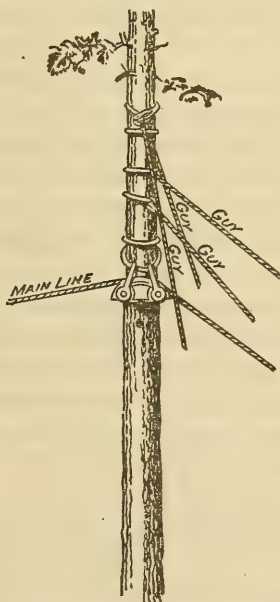


FIG. 44.—Tail tree, MacFarlane system.

line system differs from other overhead systems will be touched upon here. The location of equipment and improvements is shown in fig. 42.

Rigging.—The rigging consists of a main cable suspended between a head tree (fig. 43) and a tail tree (fig. 44). Upon this line the carriage travels. Two lines only are required to operate the carriage; one to haul it in, the other to haul it back. The main cable, leading from a drum on the logging engine, passes through a block suspended near the top of the head tree, thence out to and over a tree shoe suspended on the tail tree, and then down to a stump, where it is made fast. The haul-in line, leading from a second drum on the engine, passes through a block on the head tree in the same way as the main cable, and thence to the front end of the carriage, where it is made fast. The haul-back or trip line, leading from a third drum on the engine, passes along one side of the run, then through a block on the tail tree, and thence to the back end of the carriage.

The distance between the head and tail tree depends, of course, on the yarding distance, which in turn may be fixed by the practical range of the system. The system has been used successfully to yard logs a distance of 2,500 feet. The tail trees are from 150 to 300 feet apart, depending on conditions.

Operation.—The haul-back line hauls the carriage out along the main line to the point where the log is to be hooked on. Then the main cable is slackened sufficiently to lower the carriage to the ground, the haul-back line being used to pull the carriage to the log when the log lies to one side of the center of the run. When the choker or chokers have been attached to the carriage, the main cable is tightened until the front end of the load is raised far enough from the ground to clear obstructions. Powerful brakes on the main drum cable hold the main cable taut while the carriage with its load is pulled in. When the load is brought to the landing place, the main cable is lowered and then the load unhooked. The main cable is then tightened and the operation repeated. As logging on a run progresses, the corner trip block has to be shifted.

Logs can not be yarded from behind the tail tree, and it is difficult to yard logs on the outer edge of a wide strip near the tail tree. More power is required to raise the logs from the ground than with systems having a taut overhead cable, since the engine has to raise the cable as well as the log.

Changing lines.—One head tree is all that is required at each setting of the engine. The tail tree is changed each time a strip is logged, the new tail tree being selected and guyed before the old one is deserted. In changing lines, the lines are first drawn in to the head tree. The straw line, which is run before the change is started, is then used to run out the trip line. This operation takes from one to two hours.

Equipment.—The equipment is much the same as that used with other systems of overhead logging.

In 1911 a logging engine with four drums was built especially for use with this system. The main drum is driven through a compound train of gears by an internal gear, which revolves it in the same direction as the trip drum. The trip drum is a high-speed drum, which insures the quick return of the carriage. In front of these two drums are located the haul-in and straw-line drums. All the drums take the lead of the line on top.

The operating levers are conveniently located. The three principal drums are equipped with steam frictions, the throttles of which are banked in front of the engineer's position, immediately below the main throttle. The brake operating levers are mounted on the frame, within easy reach of the engineer's left hand.

The main and trip drums are each provided with powerful steam-operated brakes. The enginer controls the pressure exerted by the brake through the valve of the brake cylinder. The operating lever is connected to both the valve stem and cross head. When the lever is moved to any position opening the valve, the travel of the cross-head automatically closes the valve when the desired tension is reached. This forms a flexible control. The engine is mounted on a sled. The cylinders are 11 by 13 inch. The boiler, which is of the oblong fire-box type, is 66 inches in diameter. This engine costs about \$9,000 f. o. b. Portland:

The length and diameter of the lines used with this system depend on the distance between the main cable supports and the size of the timber. As a rule the main cable ranges from $1\frac{1}{4}$ to $1\frac{3}{4}$ inches in diameter. The haul-in and haul-back cables are generally seven-eighths of an inch in diameter. When the main cable is $1\frac{1}{4}$ inches it generally leads direct to the main cable drum on the engine. If one of larger diameter is used it may be necessary to use a purchase line to increase the power of the engine. Under such conditions a block is attached to the main cable. The purchase line, leading from the main-line drum, passes through this block and then down to a stump between the head tree and the engine, where it is fastened.

One company hauling second-growth timber down a steep mountain side used the following lines:

Lines.	Type of construction.	Diameter.	Length.
		Inch.	Feet.
Overhead cable.....	6 by 19	$1\frac{1}{4}$	1,800
Haul-in line.....	6 by 19	$\frac{7}{8}$	2,000
Haul-back line.....	6 by 19	$\frac{7}{8}$	4,000
Straw line.....	6 by 19	$\frac{7}{8}$	4,000
Chokers.....	8 by 19	$1\frac{1}{2}$	20 to 30
Guys ¹	8 by 19	$1\frac{1}{2}$	4,000

¹ Includes a set of guys for the tail tree.

NOTE.—The selling price of wire rope is discussed under "Ground Yarding."

The carriage has two sheaves, being light, simple, and strongly constructed. On the bottom is a large hook, to which the chokers are attached, and a small hook at each end, the haul-in line being attached to one, the haul-back line to the other. The carriage (fig. 45), with 16 by 3 inch manganese-steel sheaves, costs about \$120.

The blocks are much the same as those used in high-lead yarding. The price of overhead blocks is given under "Loading." The following gives the number, types, and selling prices of blocks used with this system at one camp:

Net selling price.

Type and size:

1 14-inch tree jack (fig. 46)-----	\$180
3 large moving blocks-----	150
2 yarding blocks-----	50
2 18-inch trip or haul-back blocks-----	50
6 14-inch trip or haul-back blocks-----	105
2 tree shoes (fig. 47) ¹ -----	100

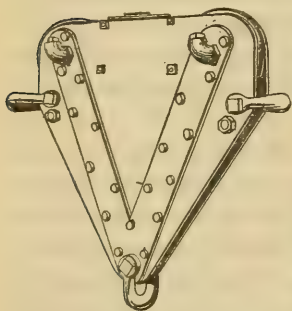


FIG. 45.—Double-sheave overhead carriage.

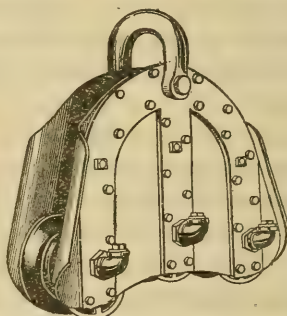


FIG. 46.—Tree jack.

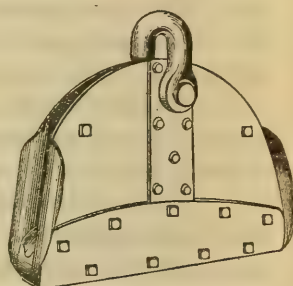


FIG. 47.—Tree shoe.

Output.—The output with this system ranges from 50,000 to 100,000 feet per day. At one camp where the logs were moved 1,500 feet down a steep slope the output averaged about 60,000 feet per day, the logs averaging about 800 feet in volume. In the same camp the output averaged from 85,000 to 100,000 feet per day on practically level ground, when the hauling distance did not exceed 1,000 feet. At another camp, where the logs were moved 2,000 feet down a steep mountain side, the output averaged about 50,000 feet per day, the logs averaging about 900 feet in volume. At still another camp, where the logs were moved about 1,600 feet down a steep slope, the country being badly broken up, the output ranged from 60,000 to 80,000 feet per day. In this latter case the timber was large, the logs averaging 2,000 feet in volume, and some of them containing 6,000 feet.

¹ A tree shoe is used to support the overhead cable at the tail tree. Since the tightening is generally done at the head tree, the outer end of this cable is stationary, making a hardwood shoe instead of sheaves practical.

Cost.—Output is the telling factor in all systems of yarding. With the same output the cost of yarding is practically the same for all systems.

The following gives the crew and the wages paid per day at one operation:

Yarding crew.

1 hook tender	\$4. 50
2 choker men	6. 50
1 unhooker	3. 25
1 signalman	3. 00
1 engineer	4. 00
1 fireman	3. 00
1 wood buck	3. 00
	27. 25

Loading crew.

1 fireman	2. 75
1 engineer	3. 25
1 head loader	4. 50
1 second loader	3. 50
1 third loader	3. 00
	17. 00

Rigging crew.

1 head climber	4. 00
1 second climber	3. 50
3 helpers	9. 00
	16. 50

It will be noted that this crew is a little larger than the ordinary crew that yards and loads logs with a ground yarding system, and that the size of the crew is practically the same as that used in connection with the Lidgerwood overhead system. A separate engine is used in loading. Under some conditions an additional choker man would be necessary.

NORTH BEND SYSTEM.

The evolving of the striking features of what is now known as the North Bend system is credited to Mr. R. W. Vinnedge, of Edgewick, Wash. It is used by a number of operators in this region because of its simplicity and the fact that it may be worked successfully with an ordinary ground yarding engine.

Rigging.—The carriage rides on a standing line. This standing line may be stretched from the tail tree to the head tree, and then anchored to stumps, as in the case of the tree-rigged Lidgerwood system; or it may lead from a drum on the engine as in the case of the MacFarlane sky-line system. The latter is the better method and

is always used when the engine makes it possible. To relieve the engine of as much of the load as possible, a block purchase is used in tightening the line. The standing cable, as suggested by its name, is not raised or lowered when the system is in operation. Obviously, however, this could be done if conditions warranted. The haul-in line is attached to the carriage. In the bight of this line, between the carriage and head tree, a butt chain lead block is hung. To this block the load is attached. The haul-back line is run out along the strip from 100 to 150 feet from the standing line, in the same manner as in ground yarding, and attached to the carriage. This line is used, in connection with a properly located lead block, to draw to any desired point the block to which the load is to be attached. The layout is shown in figure 48.

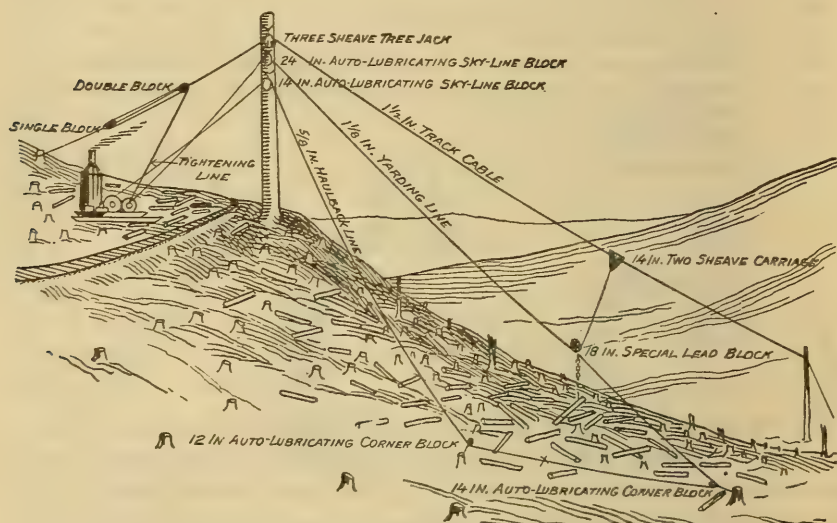


FIG. 48.—Location of equipment and improvements, North Bend system.

Equipment.—The equipment is practically the same as that used in the MacFarlane sky-line system.

An ordinary two-drum yarding engine may be used to furnish the power for this system. Mr. Vinnedge used a standard 11 by 13 inch compound-gearred yarding engine with the first installation, securing very satisfactory results. To get the best results, however, an engine differing somewhat from the standard ground yarding engine should be used. An engine designed especially for use with the MacFarlane system fulfills the requirements nicely.

One operator, after convincing himself that this system would log parts of his holdings cheaper than a ground machine, decided that the best results would be secured with a special engine. He thought, however, that this special engine could be so designed as to serve for

ground as well as overhead work. The basis of the resultant engine is one of the standard compound-g geared yarding engines. It has 11 by 13 inch cylinders, four drums, and an extended fire-box type of boiler. The gear ratio was changed so that a considerable portion of the power exerted by the main-line drum was sacrificed for increased speed. The four drums are all located within the frame and rotate in the same direction, taking the lead of the line on top. The main and trip drums are located as in the case of an ordinary compound-g geared yarding engine, the main drum being used to operate the standing line, the trip drum to return the carriage. Immediately in front of these two drums there is a shaft carrying the haul-in and straw-line drums. The gear on this shaft is driven through an intermediate gear, which meshes directly with the trip-drum gear. The haul-in drum has a capacity of 2,700 feet of $1\frac{1}{8}$ -inch line and a speed of about 600 feet per minute. The trip drum has a capacity of about 3,500 feet of $\frac{3}{4}$ -inch line and a speed of about 1,500 feet per minute. This trip drum is equipped with a large steam-operated brake for the purpose of snubbing the load down steep slopes. The brake is so designed that a varying pressure is obtainable, making it possible for the engineer to control the log under all conditions. The main drum is equipped with a ratchet and pawl for holding the standing line, since it is seldom necessary to raise or lower it. This drum is also provided with a large brake, so that, with the pawl released, the standing line may be slackened gradually. The net price of the engine f. o. b. Portland is approximately \$6,500.

The diameter and length of the standing line depend on the size of the timber, the length of the span, and the amount of deflection that can be secured. The standing lines used have ranged from $1\frac{1}{4}$ to $1\frac{1}{2}$ inches in diameter. One operator who has had considerable experience with the system is of the opinion that a $1\frac{1}{4}$ -inch cable is large enough for logs scaling 2,000 feet, and that $1\frac{3}{8}$ -inch cable should be used when the logs average from 2,000 to 4,000 feet in volume; that is, where the span does not exceed 1,500 feet. The system has given entire satisfaction when hauling as far as 1,600 feet.

The haul-in or yarding line is generally $1\frac{1}{8}$ inches in diameter, the length depending on the distance between the head and tail tree, the distance logged on each side of the standing line, and the distance the engine is from the head tree. It is economical to yard logs lying from 150 to 200 feet on either side of the standing line. To go farther results in too much strain on the equipment, also the danger of uprooting the tail tree. The wear on the yarding line when yarding downhill is almost negligible, except on that portion on which the yarding block rides. The records of one company that is using this system to haul downhill show that one $1\frac{1}{8}$ -inch haul-in line was used to yard 9,000,000 feet, the line retaining 50 per cent

of its life when it was discarded and used for chokers. The wear on this line is much greater when yarding uphill or on level ground. Still, in no case is its life as short as the main yarding lines used for ground yarding. The haul-back lines in use range from nine-sixteenths to twelve-sixteenths inch in diameter. Straw lines are generally three-eighths inch in diameter.

SWINGING.

Among the loggers of the region it is generally considered good practice to build railroads within an economical yarding distance of the timber. It is not always possible, however, to do this. It may be cheaper, because of the cost of railroad construction or the quantity of the timber, to use two or more logging engines, with or without improvements, to transport the logs from the stump to the landing. The practice of using two or more engines to transport timber over the ground—that is, without improvements—from the stump to the landing is known both as swinging and roading. In this publication the operation will be referred to as swinging, the distance from the yarding engine to the landing or pole road being considered as the swinging distance. The use of overhead logging engines for the same purpose will also be considered as swinging.

The distance it pays to swing timber is governed largely by the topography and formation of the country and by the quantity of timber in the swinging unit that can not profitably be logged direct to the landing. Under most conditions timber can be swung farther with overhead than ground logging engines.

Swinging decreases the cost of railroad construction, but it increases the cost of transporting the logs from the stump to the landing. Theoretically speaking, it is the comparison of the cost of the two methods, taking into consideration the fact that the yarding and swinging at times delay each other, that indicates whether swinging should be resorted to in a given case.

GROUND SWINGING.

It has at times been found profitable to swing logs three or four thousand feet over the ground. At times it may prove cheaper to single-haul the timber 1,200 feet or more—if the drum capacity of the yarding engine will permit—than to double-haul it. At other times it is cheaper to double-haul a shorter distance than this. Not infrequently two swing engines, in addition to the yarding engine, are used, and occasionally three swing engines are necessary.

The distance between the swing engines depends to a great extent on the topography of the country, the aim being to place them in such a way that they will not hold up the yarding engine. Under

ideal conditions the distance is a little greater than the maximum yarding distance.

In swinging, the yarding crew is the same as when the logs are single hauled. The crew used with a swing engine depends for the most part on the character of the country and output. As a rule, it is approximately as follows:

- 1 engineer.
- 1 fireman.
- 1 wood buck.
- 1 hooker on.
- 1 chaser.

If the chance is bad, an additional chaser may be necessary. In some cases no wood-buck wages, or only half the wages of a wood buck, are charged against this crew. The wages paid this class of labor are discussed under "Ground yarding."

The equipment, supplies, etc, used with a swing engine are practically the same as those used with a ground yarding engine. Both simple and compound geared engines are used. If the swinging distance is great, a simple-geared engine is used, since it has the larger drum capacity. Under most conditions the simple-geared engine is preferred. The maintenance, replacement, and depreciation of equipment, also the cost of supplies, in connection with swing engine are little less than with a ground yarding engine. (See "Ground yarding.")

OVERHEAD SWINGING.

In mountainous country overhead logging systems are particularly adapted for swinging, since on steep mountain sides logs may be swung 2,000 feet or more at a very small cost for improvements. Any one of the three systems of "overhead yarding" may be used to swing logs this distance, provided, of course, the lay of the land is such that the necessary deflection in the line can be secured.

In one case the operator was confronted with the problem of swinging timber 2,000 feet down a mountain side from a plateau to the railroad below. A ground yarding engine was set at the top of the hill, near the base of the tail tree, to assemble the logs to be swung. Eighteen hundred feet down the mountain side the head tree was located, the rise of the land for about one-half of this distance from the head tree being gentle, the rest being very abrupt, providing ample deflection for the standing line. A wide-drum ground engine was set at the railroad. The logs were swung from the tail tree at the top of the slope to the head tree by the North Bend overhead system, an especially constructed engine being used. They were hauled the remainder of the distance to the track by the ground engine, where they were loaded on cars with the gin pole and crotch

line method. About 4,000,000 feet of timber was hauled by the sky line at this setting. The overhead swing engine had no trouble in taking care of the output of the yarding engine, which averaged from 50,000 to 75,000 feet per day; in fact, it seemed it could have handled the output of two yarding engines.

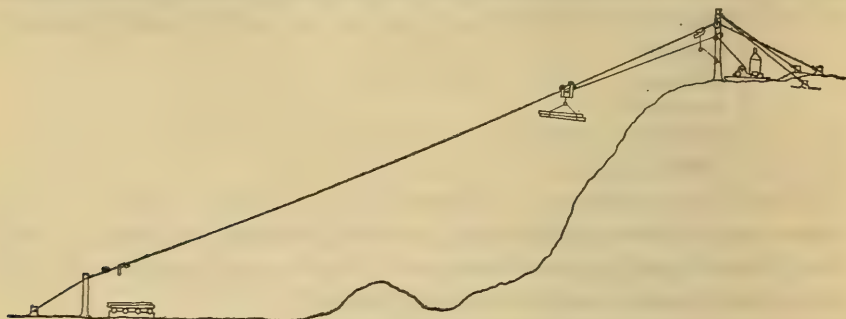


FIG. 49.—Nestos overhead snubbing system.

Under some conditions an overhead snubbing method can be used to swing logs to better advantage than any other method. This was true of the following case:

An operator had a limited amount of timber, which stood on a

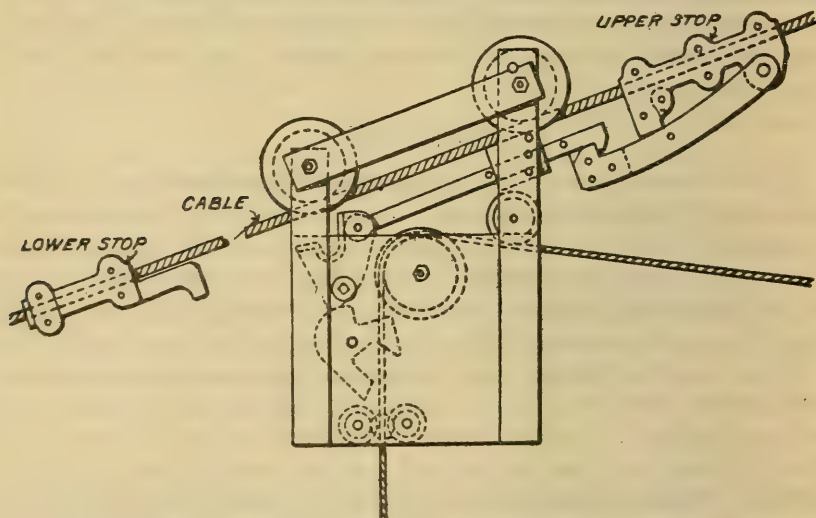


FIG. 50.—Carriage, Nestos overhead snubbing system.

bench 400 feet above the railroad, the slope between the bench and the railroad falling away so rapidly that the use of a pole road or chute was out of the question. It was decided to use an overhead snubbing system of the type shown in figure 49.

A wire cable $1\frac{3}{8}$ inches in diameter and 2,000 feet long was used as a standing line. One end of this line was fastened to a stump

near the railroad and the other end was taken up the hill, passed through a block suspended to a guyed tree about 25 feet from the ground, and made fast to a stump. Two stops (fig. 50) were clamped on the standing line, one at the top where the logs were picked up, the other at the foot where the logs were landed.

A carriage of the design shown in figure 50 was used, the snubbing line leading through it to the load.

A 10 by 12 inch wide-drum yarding engine, on which an extra wide brake had been installed, was set at the top of the slope and used to lower the logs.

Any friction drum engine with braking power sufficient to hold the load can be used. A three-drum engine could be used both to yard and lower the logs. To get the full capacity out of the system, however, one should use a separate engine with a special brake drum.

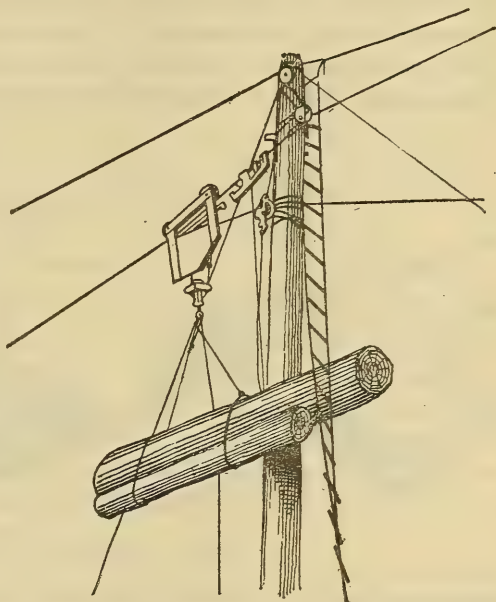


FIG. 51.—Method of hooking load, Nestos overhead snubbing system.

The load was hooked on the end of the snubbing line (fig. 51) and hoisted till a ball fixed on the snubbing line just above the hook engaged in a catch in the carriage. This catch held the load up. The snubbing-drum friction was then thrown off

and the load was snubbed to the landing place. At this point the carriage came in contact with the stop on the lower end of the line. This stop held the carriage and freed the snubbing line, allowing the load to be lowered to the ground. When the load was unhooked the signal was given to return the carriage to the woods. The ball on the snubbing line again came in contact with the catch of the carriage, releasing the carriage from the stop.

The following crew was used to operate the snubbing device:

- 1 engineer.
- 1 fireman.
- 1 wood buck (half time).
- 1 hooker on.

The loaders unhooked the loads at the landing. The chaser employed in the yarding crew, besides unhooking the logs as they were delivered to the snubber, assisted the hooker on in making up the loads for the snubber.

The operator was working in relatively small timber, and so was not in a position to say how large a log could be handled over the $1\frac{3}{8}$ -inch standing line. The largest loads handled did not exceed 2,000 feet.

The snubber handled the output of one yarding engine, about 60,000 feet per day, when working at seemingly no more than one-half capacity. When working intermittently it made 50 trips per day, and it could have made 75 trips per day easily.

In transporting large timber across canyons on a standing line, where conditions are such that the logs must be entirely suspended,

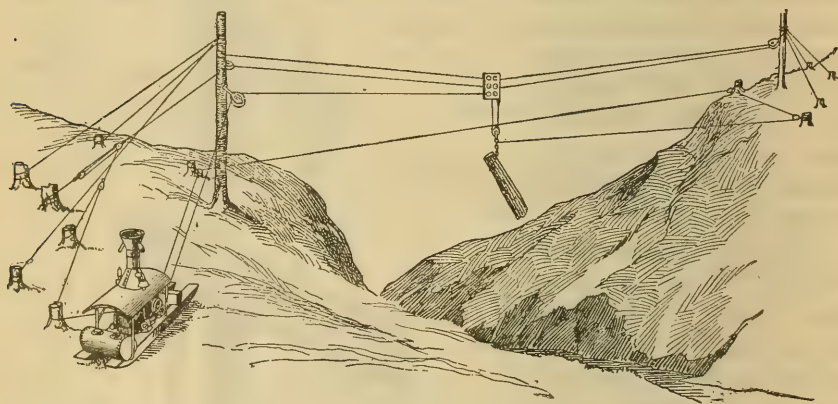


FIG. 52.—Double sky-line system.

some operators have found it necessary to use a double standing line. The rig used by one operator is shown in figure 52. The method of tightening the double standing line, which is made of $1\frac{1}{4}$ -inch wire rope, is indicated in the figure, the power being furnished by the gypsy head on a standard wide-drum logging engine. The carriage, which is 3 feet 6 inches by 4 feet 6 inches, has five 14-inch sheaves. The tree jacks, through which the standing line leads, have three 16-inch sheaves. The main line lead block has a 24-inch sheave. A 1-inch main line and a $\frac{5}{8}$ -inch trip are used.

The rig has worked successfully with a span of 2,200 feet, hauling logs scaling as high as 7,000 feet.

ROADING.

Under some conditions rather large bodies of timber are transported for long distances with ground logging engines, necessitating and justifying the use of pole roads. This is known as roading.

In the past it was the common practice in this region to road logs long distances to mills, drivable or towable waters, or railroads. At the present, however, roading is used only to a limited extent by loggers who are in a position to use the best methods, most of it being done in the Grays Harbor and Willapa Harbor regions. This is because the railroad, with the geared locomotive, has proved the better method. With railroad inclines and overhead logging methods perfected, long-haul ground logging will be used less as time goes on.

In the Grays Harbor and Willapa Harbor districts more logs have been, and are, driven than in all the rest of the Douglas fir region taken together. In many cases a pole-road haul of a mile or two delivers all the logs to a drivable stream, making roading a more satisfactory method of transporting logs than the railroad. Then, too, material satisfactory for railroad ballast is not infrequently scarce in the Willapa Harbor district. This, in connection with the fact that the rainfall is very heavy, makes the cost of railroad maintenance high and works in favor of the roading method in many cases.

METHOD.

While it is sometimes economical to haul logs 2,000 feet or more over a dirt road, as a general thing a fore-and-aft or pole road is built when the distance from the yarding engine to the railroad, stream, or mill equals or exceeds 2,000 feet. In the early days skid roads were used. This was the type of road used in connection with draft power, and it was natural for the logger to continue using it for a while with the logging engine. Some operators still build a part of the road of skids.

The logs are yarded, or yarded and swung, to these pole roads in the same manner as to railroads. They are then made into turns ranging from 6,000 to 12,000 feet, and hauled to the railroad, stream, or mill by a roading engine. One road engine may be ample, since under ideal conditions such an engine can haul logs for a little more than a mile. Not infrequently, however, a battery of road engines is necessary to haul the logs out of the woods, the rear machine taking the logs from the yarding engine and delivering them to the tail block of the succeeding road engine, and so on to the landing. It is seldom economical to employ more than two or three machines in a battery because of the cost for labor, wire rope, maintenance, etc. The general features of the road engine are the same as those of the simple-gear yarding engine, the striking difference being the rope capacity of the drums.

The main, or hauling, line is operated on the slack-rope principle, or in the same way as in ground yarding, with the road engine located at the landing and a heavy tail block swung a short distance

above the yarding engine. The trip line, which is strung near the pole road in such a way that it will not interfere with the operation of the main cable, leads through trip blocks located at suitable points and then through the tail block, where it is attached to the woods-end of the main line. The main cable follows the road and is kept in place with blocks or rollers where turns are made.

From six to eight logs, depending on their size and the character of the road, are fastened one behind the other by means of grabs or dogs (figs. 53 and 54), forming turns, which are attached to the main cable. The turns are made up by a grab man. A chaser follows the logs to the landing, often riding in a rigging sled hollowed out of a log, which is attached to the rear log. He can signal to the road engineer at any point along the line by pulling on a wire which is stretched from the road engine. On arrival at the landing the chaser aids in placing the logs on the landing, removes the grabs from the logs, and returns with the grabs in the rigging sled

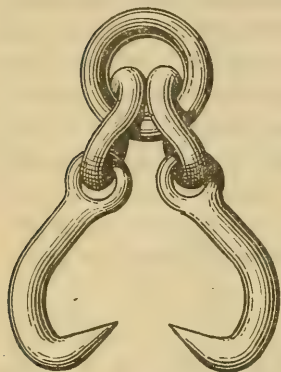


FIG. 53.—Coupling grabs.

to the yarding engine. In some cases, especially where the pole road is so steep in places that gravity causes the logs to run faster than the lines travel, the logs in the turn are not dogged up and pulled to the landing. Instead, they are pushed into the landing, a hook attached to the main line being made fast to the rear log. By this method several turns of logs of the ordinary size may be along the road at different points at one time.

It is practically impossible to say how far a road engine works on the average. Unless conditions are particularly favorable one machine will not be able to haul farther than 3,000 feet; in many cases less than this. At this distance a road engine should generally be able to handle the output of two yarding engines.



FIG. 54.—Logging dog.

EQUIPMENT.

Road engines.—Simple-geared, wide-drum engines are used for roading, the size and drum capacities depending on the size of timber, character of road, and length of haul. They are mounted on sleds the same as ground yarding engines and moved over the ground from one setting to the other by their own power.

Lines.—The lines are the same size as those used in ground yarding, in some cases a little smaller. The trip line is roughly twice the length of the hauling line.

Grabs, dogs, and hooks.—Many kinds of equipment and methods are used to fasten the logs together in a turn. Ordinarily the logs are connected one behind the other with grabs or dogs. The grabs are made in different forms and the methods of using them differ somewhat. Figure 53 shows a pair of grabs, the cost of which amounts to \$6 or \$7. A pair of grabs is inserted in the end of each log, the grabs on the adjoining logs being connected with a short piece of cable. Some operators fasten the logs together with dogs of the type shown in figure 54. Two dogs are inserted in the end of each log on opposite sides, the short pieces of cable connecting the dogs of adjoining logs crossing each other in the form of an X. Dogs cost from \$2 to \$5 per pair. In some cases only the last two logs are dogged together, and the outer end of the main line is attached to the next to the last log with double chain grab hooks.

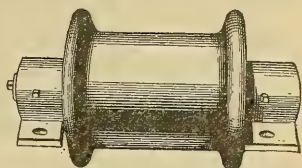


FIG. 55.—Road roller.



FIG. 56.—Road hook.

Blocks.—The number and type of blocks used in roading depend on the character of the road and the length of haul. In a general way, the same blocks are used in roading as in ground yarding. No large butt-chain lead blocks, however, are necessary.

Rollers.—When there are turns in the road, rollers are placed vertically on stumps or posts to keep the line leading with the load, to prevent wear on the cable, and to reduce friction. Rollers are also placed on the high points to prevent wear from downward pressure. Figure 55 shows one of the types of rollers used. The selling price in 1916 of this roller, smooth or corrugated, when made of manganese steel was as follows:

Net selling price.

8 by 12 inch, with 2-inch shaft.....	\$32
8 by 16 inch, with 2-inch shaft.....	36
10 by 16 inch, with 2½-inch shaft.....	40

Where the logs are pushed or kicked over the pole road instead of being pulled, a hook taking the form of the one shown in figure 56 is sometimes used. The guard lies back against the shank of the

hook when the hook is in use, and automatically drops over the point of the hook when the hook is run back by the trip line, thereby protecting the point and preventing the hook from catching or hanging up when the line is run back. This hook costs from \$13 to \$17, depending on the size.

Miscellaneous equipment.—Practically all the differences in equipment between roading and ground yarding will be suggested by the peculiarities of the two methods, making it unnecessary to enter into a discussion of the miscellaneous equipment used in roading.

Special equipment.—When the road is so steep that the turn of logs runs, special devices are sometimes used.

(a) One of these, the cable grip, is shown in figure 60. At one camp where the grip is used the operator had to contend with the following conditions:

The topography of the country was such that the logs had to be hauled from one-half to 2 miles over pole roads by road engines.

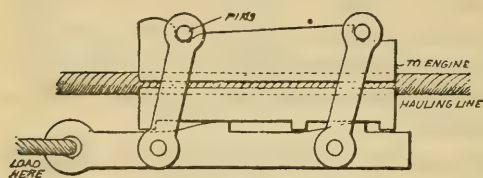


FIG. 57.—Road cable grip.

The aim was to secure a favorable grade of about 5 per cent. Too often the topography of the country was such that the grade in places was much steeper than this, amounting to 50 per cent at times. At one

time two roads, each of which was from three-fourths to 1 mile in length, were used. One of these had a rise of 150 feet in the first 2,000 feet; from then on for a distance of 2,000 feet the rise was 550 feet, giving an average grade of $27\frac{1}{2}$ per cent. A part of the road in the last stretch rose 350 feet in 1,000 feet, the grade for 300 amounting to 50 per cent. While the aim was to make the roads as straight as possible, it was necessary to put in curves to cheapen the construction cost.

About 100,000 feet of timber per day was hauled over this pole road. This output, however, only indicated the possibilities of the method under these conditions; considerably more, without doubt, could have been handled. On another road, which was about $1\frac{3}{4}$ miles in length and had grades equally bad, a little more than six trips per day were made, 15 logs, having an average volume of 1,200 feet, being taken at a turn.

The success of these long hauls was attributed to the cable grip (fig. 57), by means of which the turn of logs is attached to the hauling line. It consists of two jaws which have a gripping action when the strain of the load is brought to bear on it. This action automatically clamps the line between the jaws with sufficient force to

haul the load. Whenever the load starts to travel faster than the line, the jaws are released, permitting the grip to slide along on the hauling line. Because of this the lines are not snarled and blocks are not torn down, neither is there the amount of line breakage that would occur under other conditions, since when the load slows down the grip takes hold gradually, the result being that the load does not stop. This continuous movement of the load could not be secured if the load were fixed rigidly to the line or if the load were attached to the line with a sliding ring, which would be engaged by a "bull ring" on the end of the line when the load was picked up.

(b) Another device (fig. 58) is used with an endless line to snub logs down steep chutes. The endless line is wound around the two 42-inch drums—one grooved for four turns, the other for five—four times in the form of a figure "8." It is operated by means of one lever, which keeps the line from slipping and enables the two brakes to hold the line in control on any grade. Two rings are fastened to the snubbing line, which is strung along the road, one at the machine, the other at the tail block at the bottom of the hill. One company used this device to lower logs a drop of 500 feet in one-half mile, some of the grades being nearly 40 per cent. The logs were hauled over a pole road by a road engine for a distance of 1 mile, the turns averaging six logs. At the head of the sharp incline the turn was stopped opposite the snubbing machine and fastened to the snubbing line. A man took his place at the brake of the snubbing machine, the signal was given, and the road engine started the turn down the chute, the man at the machine regulating its speed down the hill and stopping it at the bottom. The machine costs about \$600.

Several other types of snubbing machine are used. Figure 59 shows the method of using a compressed-air snubbing machine.

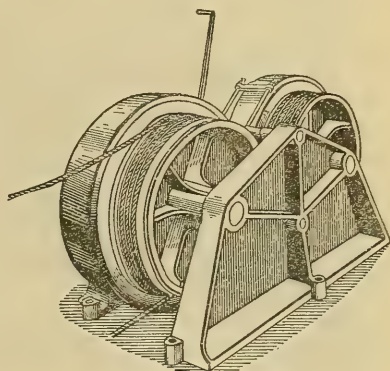


FIG. 58.—Snubbing device.

IMPROVEMENTS.

The improvements in the main consist of pole roads or chutes, which, in short, are troughs formed by laying two or more strings of logs side by side on the ground or on sills. These require a right of way from 12 to 14 feet wide, which is swamped out carefully and graded to avoid abrupt changes. It is better to make cuts than fills, since a more solid foundation is thus secured.

Fore-and-aft roads may be constructed on almost any grades. The usual grade of a downhill road ranges from 5 to 25 per cent. Grades of 30 per cent or more, if of considerable length, are likely to lead to trouble through the logs running and jumping out of the road. Adverse grades may and do occur in these roads, although it is preferable to keep the adverse grades down to 10 or 15 per cent.

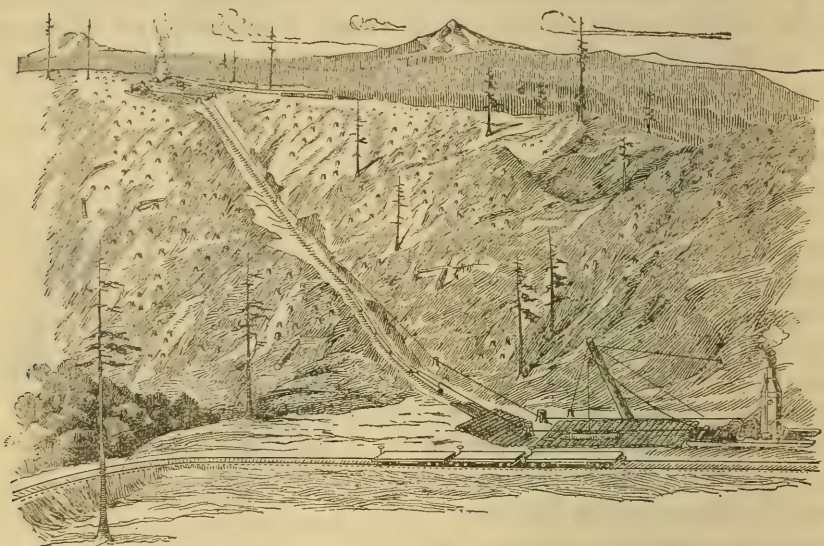


FIG. 59.—Method of using compressed air snubbing machine.

Roads having adverse grades of 40 or 50 per cent have been used. An engine is generally required at the top of any long or very steep adverse grade.

The best results are obtained from straight roads, because curves increase the friction, reduce the hauling ability of the engine, cause greater wear on the cable, make it difficult to keep the logs in the road, increase the maintenance cost of the road, and curtail the output. Curves, however, are necessary in many cases to change the general direction of the road. Short curves or reverse curves are out of the question, and usually not more than two or three curves are practicable, even in the longest roads. A change of 90 degrees in the direction of a road may be made by means of two long and gradual curves.

In constructing the roads the ends of the logs are joined together, the tops being placed in the direction in which the logs are hauled. In the case of a two-pole road the logs are placed from 6 to 8 inches

apart, the inner sides being hewed in such a way as to form a trough 10 inches wide at the bottom and 30 inches wide at the top. Cross skids, placed at 10-foot intervals, are used to support the road across depressions, and braces are used to prevent spreading. Where the road is embedded in the ground skids and braces are not necessary except at the joints. Where possible inferior species are used as construction material, the logs being 60 or 70 feet long and from 14 to 30 inches in diameter at the top. In some cases a wider road is necessary or preferred, making the use of three or more strings of logs necessary. Two logs are placed in much the same way as above, and a third log embedded in the ground between them. The outside logs are from 14 to 30 inches in diameter at the top, the bottom log a little smaller.

The labor cost per linear foot for these improvements ranges from \$0.25 to \$0.50 for a pole road, and from \$0.50 to \$0.75 for a chute road. One operator is of the opinion that pole roads can be constructed at a labor cost of \$0.30 per linear foot; chutes at a labor cost of \$0.50 per linear foot. In one case the labor cost of building 1,000 feet of pole road amounted to \$250, which is at the rate of \$0.25 per linear foot. The road was constructed on steep, side-hill ground and consisted of two strings of logs. Two small canyons had to be crossed, which required two spans of 100 feet each. Two logging engines, working toward each other, were used, the time required to complete the stretch of road amounting to six days.

COST.

It is not practicable to deal with the cost of roading per thousand feet except in a very general way, since the work is carried on under so many different conditions.

Labor cost.—A road-engine crew is usually made up of an engineer, fireman, wood buck, chaser, and grab man. When the roading engine is hauling from two yarding engines, an additional grab man is employed. The wages paid the crew are discussed under "ground yarding."

The average operating labor cost per thousand feet ranges from 10 to 50 cents, depending for the most part on the amount of timber transported over the road to the landing and on the number of roading engine crews used. To illustrate the effects of natural conditions on roading costs, the following hypothetical statement is given. It is based on the assumption that a road engine is hauling 3,000 feet, that the output of two yarding engines is hauled to the landing, and that the output of the yarding engines varies with the size of the timber.

Hypothetical statement showing the effect of output on the operating labor cost per thousand feet for roading.

Volume of average log.	Roading output per day.	Labor cost per thousand feet.
<i>Feet.</i>	<i>Feet.</i>	
2,000	180,000	\$0.11
1,750	155,000	.13
1,500	135,000	.15
1,250	125,000	.16
1,000	110,000	.18
750	90,000	.22

The labor cost per 1,000 feet would have been twice as high if it had been based on the output of one yarding engine instead of two. The same thing would have happened if the cost had been based on the use of two roading engines instead of one. If the cost had been based on the assumption that two roading engines, working tandem, would handle the output of one yarding engine, it would have been four times as high.

Wire rope.—The cost of wire rope per 1,000 feet is rather heavy, nearly equaling in some cases the operating labor cost. An average cost would serve no practical purpose. From the standpoint of a timber appraisal, it is safe to figure that the hauling line will handle 10,000,000 feet; the trip line, 15,000,000 feet. The lines used vary somewhat in diameter. As a rule, however, the main or hauling line is made of 1½-inch rope; the trip line of five-eighths inch.

Maintenance and depreciation of roading engines.—Roading engines are not subject to so much strain as ground yarding engines. And as they are of the simple-gear type, they are not so complicated in make-up. This results in a lower maintenance cost. It also tends to give roading engines a little longer life than the compound-gear yarding engines. The maintenance cost of logging engines, also the amount that should be written off annually for depreciation, is discussed under "Ground yarding."

Improvements.—The cost of pole roads per thousand feet ranges from 20 to 50 cents, the amount in a specific case depending on the total cost of the road and the volume of timber hauled over it.

Other costs.—The cost of fuel, blocks, hooks, rollers, lubricants, waste, and packing for roading is practically the same as for ground yarding.

LOADING.

METHODS.

A number of methods are used in loading logs on railroad cars or trucks. Here, as in other departments of the logging operation, personal ideas of operators conflict to some extent. A method that satisfies one superintendent under certain conditions might not satisfy

another. There is no disagreement, however, as to what in a general way constitutes a proper method, since all agree that it should be adapted to the conditions; that it should facilitate and not delay yarding; and that it should do the work at a minimum cost.

PARBUCKLE METHOD.

Logging jacks in connection with skids or landings were first used to load logs in the region. This method, being slow, was soon superseded by the parbuckle method, which resembles the cross-haul method of the East. The parbuckle method is still extensively used in the Grays Harbor country. One hundred thousand feet of timber per day can be loaded satisfactorily with it where the logs average 2 or 3 feet in diameter and 40 feet in length. It requires a more elaborate and costly landing than other loading methods.

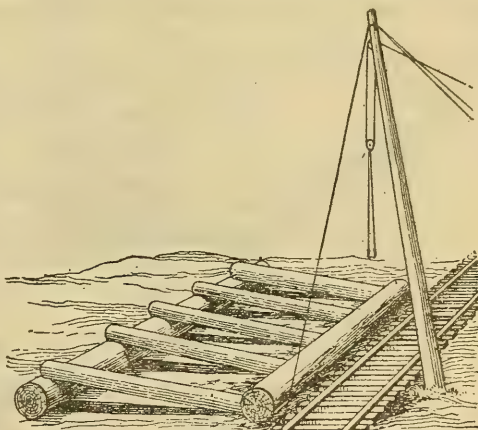


FIG. 60.—Common type of deck landing.

A gin pole is erected on the side of the track opposite to the landing, to which a single sheave loading block is attached about 30 feet from the ground. The loading line, leading from the drum that furnishes the power, passes through the loading block, then around the logs to be loaded, and thence over the car to the base of the gin pole where it is hooked. When the power is exerted on the line the log is rolled from the landing to the car.

SINGLE GIN-POLE METHOD.

In many cases the loading rig consists of a single gin pole about 60 feet in height, a main loading line, crotch lines, and hooks, tongs, or slings, the power being furnished by a loading drum on the roading or yarding engine or by the main drum of a separate loading engine (fig. 60). The gin pole is erected on the side of the track opposite the landing and just far enough from the track to permit the passage of cars, and with the top, or the part to which the rigging is hung, over the center of the track. A 1-inch main loading line, leading from the engine, passes through a 14 by 2 inch corner block at the top of the gin pole, and then down to the log. Two lines, called crotch lines, from 25 to 30 feet in length, depending on the length of the logs and whether loading hooks or tongs are

used, are attached to the end of the main loading line. The crotch lines are attached to the logs by means of hooks, tongs, or slings (figs. 51, 61, and 62). Where more power is necessary because of the size of the logs, a 14 by 2 inch fall block in addition to the corner block is used (fig. 60). In such cases, the main loading line, generally seven-eighths inch in diameter, passes through the corner block, then through the fall block, and thence to the top of the gin pole, where a "tail hold" is taken.

This method followed the parbuckle method, and was very generally used. The last three or four years it has been giving way

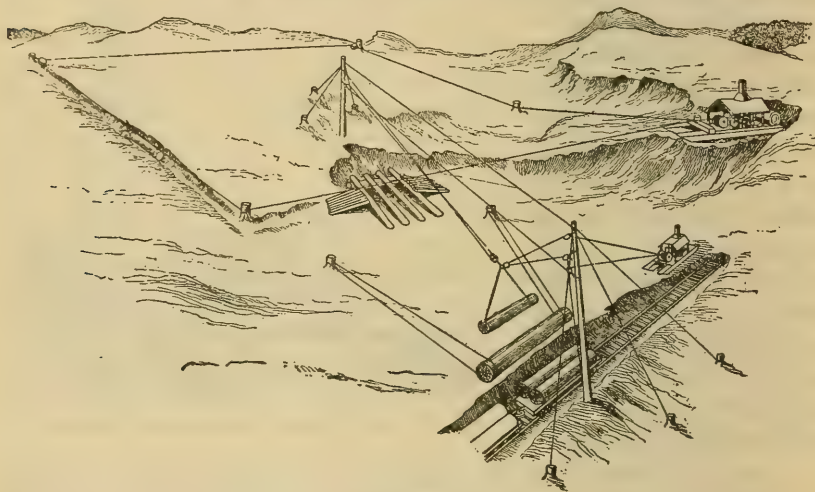


FIG. 61.—Overhead loading system.

to overhead loading methods. It requires landings (of the type shown in fig. 60), which is its most objectionable feature. Landings adapted for this method must be made small because of their cost, and so afford insufficient storage space. This method is not so fast as overhead methods, neither does it allow the loaders the privilege at all times of deciding the order in which the logs shall be loaded.

The fixed investment in equipment at one side with this method, where the power is furnished by a separate loading engine and no fall block is used, amounts to about \$2,718, as follows:

1 7 by 10 inch double-drum loading engine.....	\$1, 625
1 set of guy lines.....	100
1 main loading line.....	85
1 spotting line.....	45
3 14 by 2 inch loading blocks.....	63
Loading-engine repair parts and materials.....	75
Loading-engine sled.....	250
Oil-burner equipment, including oil and water tank.....	375
Miscellaneous equipment.....	100
Total.....	2, 718

The statement includes equipment in use as well as on hand.

If a fall block is used, the fixed investment will amount to \$2,739. If a fall block is used and the power is furnished by a loading drum rather than by a separate loading engine, the fixed investment will amount to about \$500, the cost of the loading drum amounting to \$150.

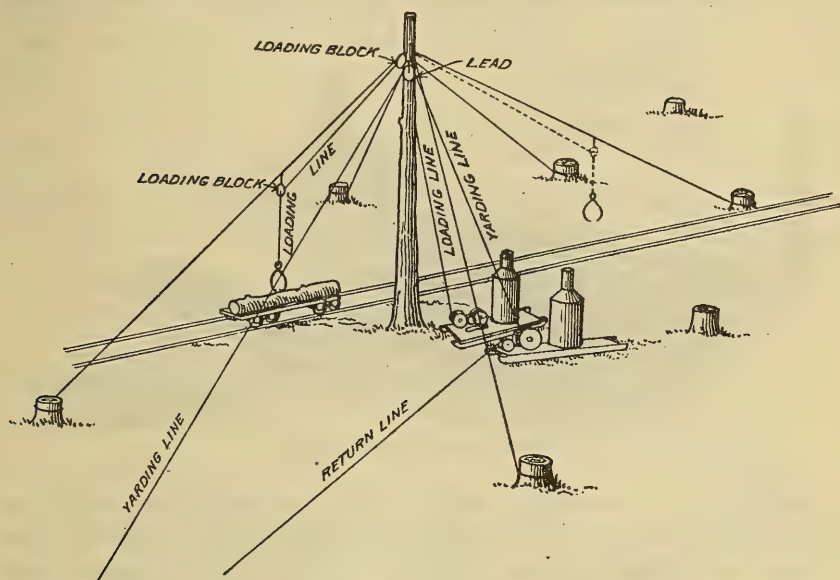


FIG. 62.—Single guy-line loading system.

OVERHEAD METHODS.

In the last few years overhead loading systems have been adapted to coast timber. These systems, while varying considerably in details, are based on two rather distinct principles:

(1) One overhead loading system has no standing line (fig. 63). It has two wire-guyed gin poles, which are from 100 to 200 feet apart. The head pole is about 60 feet in height and erected on the side of the track opposite the landing. The tail pole is from one-fourth to one-third the height of the head pole and placed back of the landing. Occasionally it is possible to use a high stump for a tail tree. The $\frac{3}{4}$ -inch main or hoisting line leading from the main drum of a separate loading engine is reeved through a double-sheave corner block suspended at the top of the head pole and a single-sheave fall block hung in the bight of the line, the tail hold being taken on the fall block. Another line, the trip line, about five-eighths inch in diameter, leading from another drum on the engine, passes through a 12 by 2 inch corner block at the top of the

head pole, then through another block of the same size on the tail pole, and thence to the fall block of the hoisting line, where it is attached. With crotch lines attached to the fall block, the largest logs can be lifted from the landing and moved toward or away from the car.

In one case, the power is furnished by a $9\frac{1}{2}$ by 10 inch double cylinder engine, steam being supplied by a 50 by 120 inch vertical

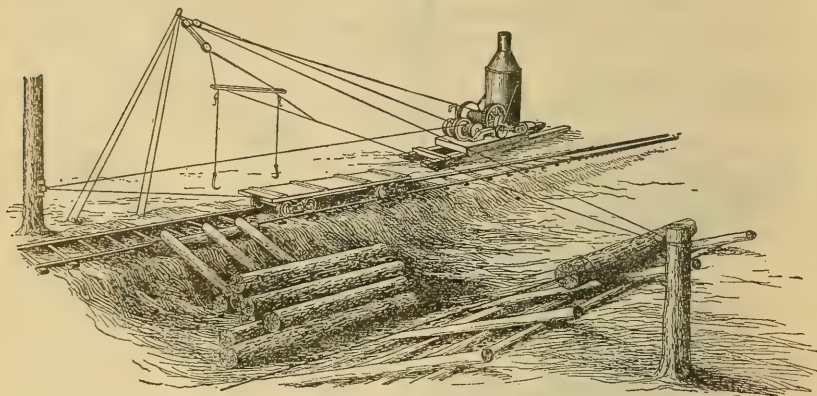


FIG. 63.—Overhead loading system.

boiler, having a working pressure of 175 pounds. The upper or main drum carries the hoisting line. On the front shaft are two drums, one of which carries the trip line, the other the straw line. By means of the straw line, cars can be moved at the pleasure of the engineer, the power furnished being ample to "spot" six loaded cars on a $2\frac{1}{2}$ per cent grade. The three drums are operated by three separate friction devices, making them independent of each other. The car and the load are under the control of the loading engineer at all times. The load is lowered by means of a powerful steam brake, thus eliminating the danger of dropping a log, which might injure a loader or break a car.

In some cases the $\frac{7}{8}$ -inch hoisting line, leading from the main drum, passes through a 14 by 3 inch single-sheave corner block at the top of the head pole, then through a fall block of the same size, and thence to the gin pole, where a tail hold is taken. The scheme is shown in figure 61. In other cases, one of the trip-line corner blocks is hung on a $1\frac{1}{4}$ or $1\frac{1}{2}$ inch guy instead of a tail tree, the guy line, which is called the front guy line, being strung from the top of the head pole to a stump at the back of the landing. The scheme is shown in figure 64.

The fixed investment in equipment at one side with this method, when a double-sheave corner block is used, is about \$4,193, as follows:

1 9 by 10 inch three-drum loading engine.....	\$2, 825
1 set of guy lines.....	100
1 main loading line.....	140
1 trip loading line.....	100
1 spotting line.....	45
2 double-sheave blocks.....	120
2 single-sheave blocks.....	63
Loading engine, repair parts, and materials.....	75
Loading engine, sled.....	250
Oil-burner equipment, including oil-and-water tank.....	375
Miscellaneous equipment.....	100
Total.....	4, 193

NOTE.—The statement includes operating equipment as well as equipment on hand.

In many cases two sets of crotch lines, a spreader, and a set of loading lines (figs. 63 and 64) are used instead of one set of crotch lines.

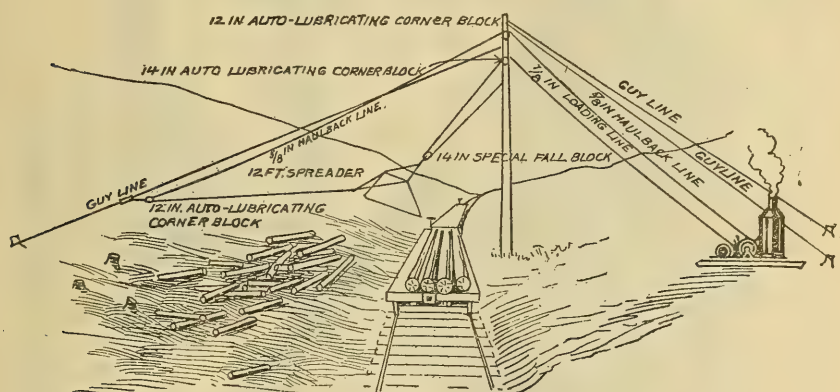


FIG. 64.—Overhead loading system.

the spreader giving the engineer much better control of the log when it is in the air than the unmodified crotch line device (fig. 61), because it checks the tendency of the log to swing back and forth several times before it can be lowered to its position on the car. The spreader is about 12 feet long and is made of 45-pound railroad iron. The crotch lines are attached to the ends of the spreader by means of 1½-inch clevises, the crotch of the upper or hoisting set being about 8 feet from the spreader, the crotch of the trip set about 10 feet from the spreader. The loading lines are about 18 feet long, which is ample for logs up to 40 feet in length. Attachments are used for longer logs. This device increases the fixed investment about \$50.

With this system the landing place can be made very wide, sometimes 150 or 200 feet, since few or no landing improvements are necessary. No yarding time is lost because of blocked-up landings; 100,000 feet or more of logs can be stored, so that the yarding crew can continue at work after the loading crew has been forced to stop

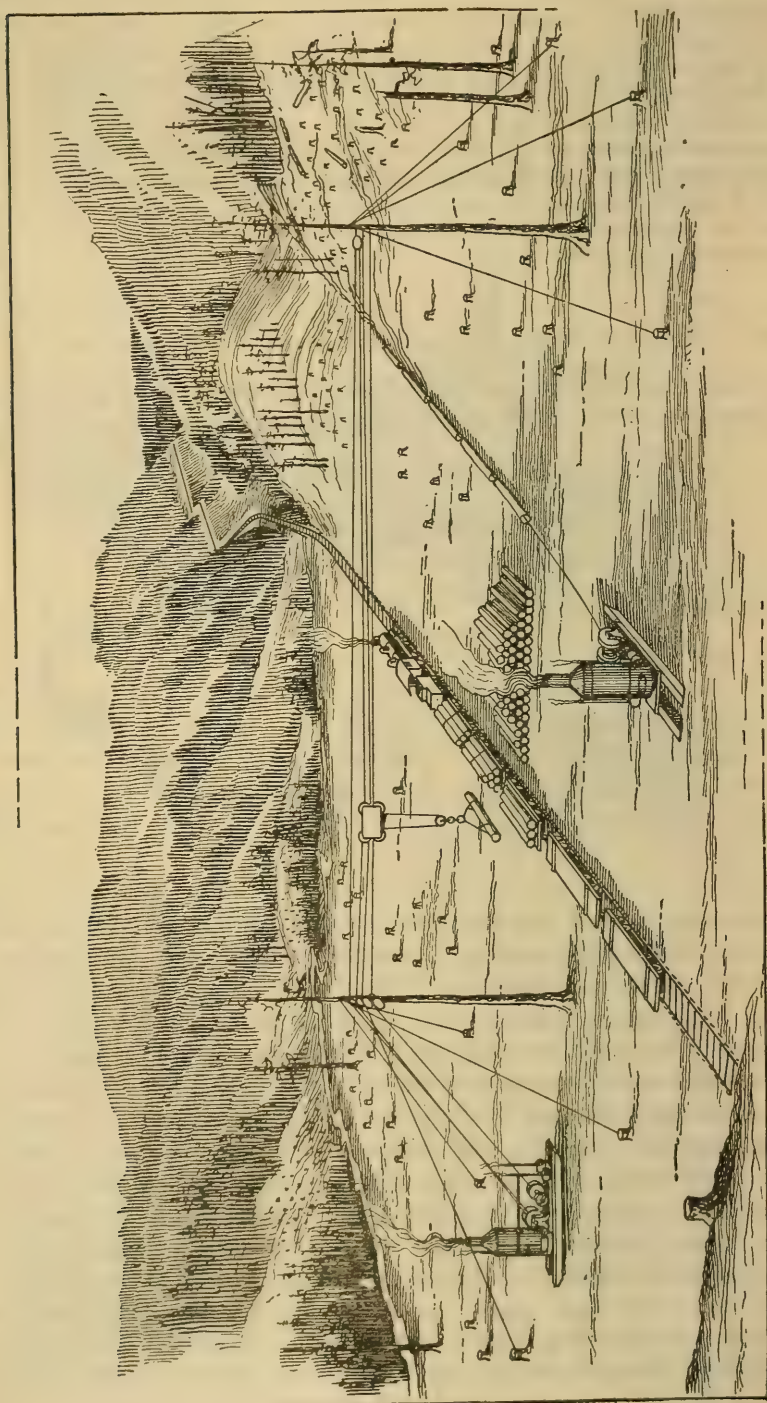


FIG. 65.—Overhead loading system.

because of a breakdown in the loading or railroad department. The system enables the loaders at all times to select the most desirable logs from the standpoint of making up a carload, which can not be done with the single gin-pole method. Furthermore, better settings can be secured for the yarding engines. In one instance the logs were yarded in on one side of a ravine, while the railroad and loading engine were operated on the other. The bottom of this ravine was about 30 feet below the level of the track, providing storage space for more than 600 logs. The largest yarding output can easily be handled with this method. Landings may or may not be used. Some operators feel that they are essential because they protect the cars and facilitate ground yarding. In any case they are simple in construction (fig. 61).

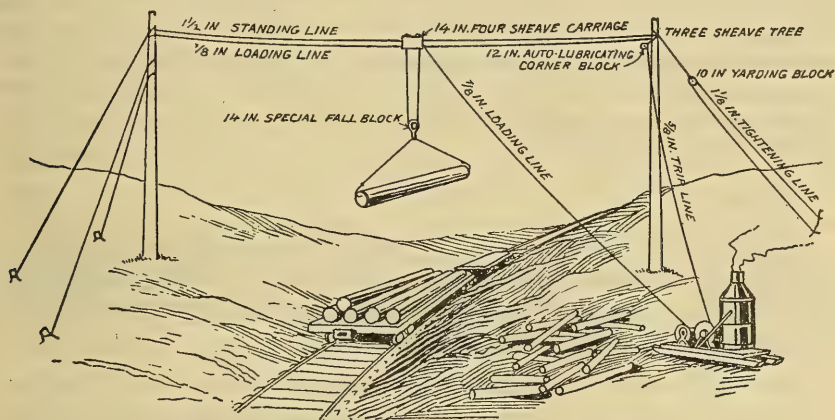


FIG. 66.—Overhead loading system.

(2) A standing line is used with the other type of overhead system (fig. 65). Two well-guyed trees or gin poles are used, one on each side of the track. These can be anywhere from 200 to 800 feet apart, the distance depending on the chance, and so located as to permit the loading of logs from either side of the track at one setting. A $1\frac{1}{2}$ -inch standing line is stretched taut from one pole to the other at from 40 to 60 feet from the ground. A 14-inch four-sheave carriage, riding the standing line, can be racked in either direction at a speed of about 800 feet per minute by two three-fourths inch trip lines. The trip lines, leading from opposite ends of the carriage, pass through 14 by 2 inch corner blocks suspended at the top of the gin poles to the two upper drums of a three-drum, four-cylinder loading engine. The seven-eighths to 1 inch main or lifting line, leading from a tail hold on one of the gin poles, passing through the two lower sheaves of the carriage, looping down and supporting a 14 by 2 inch fall block in the bight of line, then through a 14 by 2 inch

corner block on the other gin pole, and thence to the lower drum of the engine. The lifting line is handled independently of the trip lines, making it possible to raise or lower the load while the carriage is running on the standing line.

The fixed investment with this method varies considerably, depending for the most part on the distance between the spar trees. It would seem that it should never exceed \$5,337 at one side, as follows:

1 four-drum loading engine.....	\$2, 700
2 sets of guy lines.....	200
1 standing line.....	550
1 14-inch four-sheave carriage.....	150
2 trip lines.....	330
1 loading line.....	300
7 14 by 2 inch blocks.....	147
2 tree shoes.....	60
1 spotting line.....	100
Loading-engine repair parts and materials.....	75
Loading-engine sled.....	250
Oil-burner equipment, including oil and water tank.....	375
Miscellaneous equipment.....	100
Total.....	5, 337

Where it is desired to load on only one side of the track at a setting, only one trip line is used. The scheme is shown in figure 66. Under such conditions the fixed investment should not exceed \$4,900, since the cost of blocks and trip line is less.

GUY-LINE METHOD.

The guy-line method of loading is not infrequently employed with overhead and high-lead yarding methods, for which it is particularly adapted. As a rule, the head spar tree used with these yarding methods is guyed with from 6 to 11 lines, 2 of which can be so arranged as to permit the attachment of a loading block at a point directly over the center of the track and about 60 feet from the ground (fig. 62). The loading line, leading from its drum on the loading engine, passes through a block on the head spar tree, thence through the loading block suspended to one of the loading guy lines. In some cases the latter block is attached to a loading carriage, which in turn is supported by the loading guy line. A pair of tongs is attached to the loading line, the weight of which is sufficient to prevent the loading line from running back through the block. Where the yarding and loading engines are mounted on separate sleds the location of the loading engine, as related to the location of the yarding engine, depends on the chance. The yarding and loading engines may be placed side by side on the same side of the track, as near the foot of the head spar tree as possible, with the loading engine next to the track, the logs being loaded directly to

the cars from the point of delivery of the yarding engine. In many cases the loading engine is mounted on the same sled or car as the yarding engine, the combination machine being set as close to the head spar tree as possible.

When the yarding output is large, this method is not entirely satisfactory, since the logs can not be loaded with it as fast as they are yarded. In an attempt to remedy this condition and still use practically the same method, some operators are using two loading lines instead of one (fig. 34). The two lines lead from the loading engine and pass through blocks suspended on guys immediately over the car to be loaded, in the same manner as in the case of the single loading line method. One loading engine designed especially for this method consists primarily of two independent loading engines mounted on a common frame. The drums are fixed to the shaft and can be operated in the same direction or opposite directions at the same time, being controlled by two throttle levers. The cylinders are 9½ by 10 inches. The loading engine is mounted on a 125,000-pound capacity car, immediately in front of the yarding engine. The yarding and loading engines and car form a complete yarding and loading unit, somewhat similar to the tree-rigged Lidgerwood overhead skidder. It is not necessary, of course, to mount the loading and yarding engines on a car. Certain advantages, however, result from this arrangement, such as the saving of time when moving, and the elimination of a loading fireman, the loading engine taking its steam from the same boiler as the yarding engine. When operators are properly equipped to get the most out of this equipment, the loading and yarding engines are mounted on a steel car with swivel trucks, the swivel trucks making it possible to set the car to one side of the track without constructing a siding.

The fixed investment in equipment with this method at one side, where two loading lines are used, amounts to about \$4,420, as follows:

1 9½ by 10 inch Duplex loading engine.....	\$3,000
2 loading jacks.....	120
2 loading guys.....	225
5 blocks.....	110
2 loading lines.....	120
1 spotting line.....	45
Loading engine repair parts and materials.....	75
Loading engine sled.....	250
Oil burner equipment, including oil and water tank.....	375
Miscellaneous equipment.....	100
Total.....	4,420

NOTE.—The statement includes operating equipment as well as equipment on hand. Duplex loading engines without boiler cost from \$2,200 to \$2,400. A steel car costs about \$2,000; with air brakes, \$2,200.

SWINGING BOOM LOADING DEVICE.

It has been found in handling medium to small-sized logs in heavy stands with the Lidgerwood tree-rigged skidder that not infrequently more logs can be yarded than can be loaded with the guy-

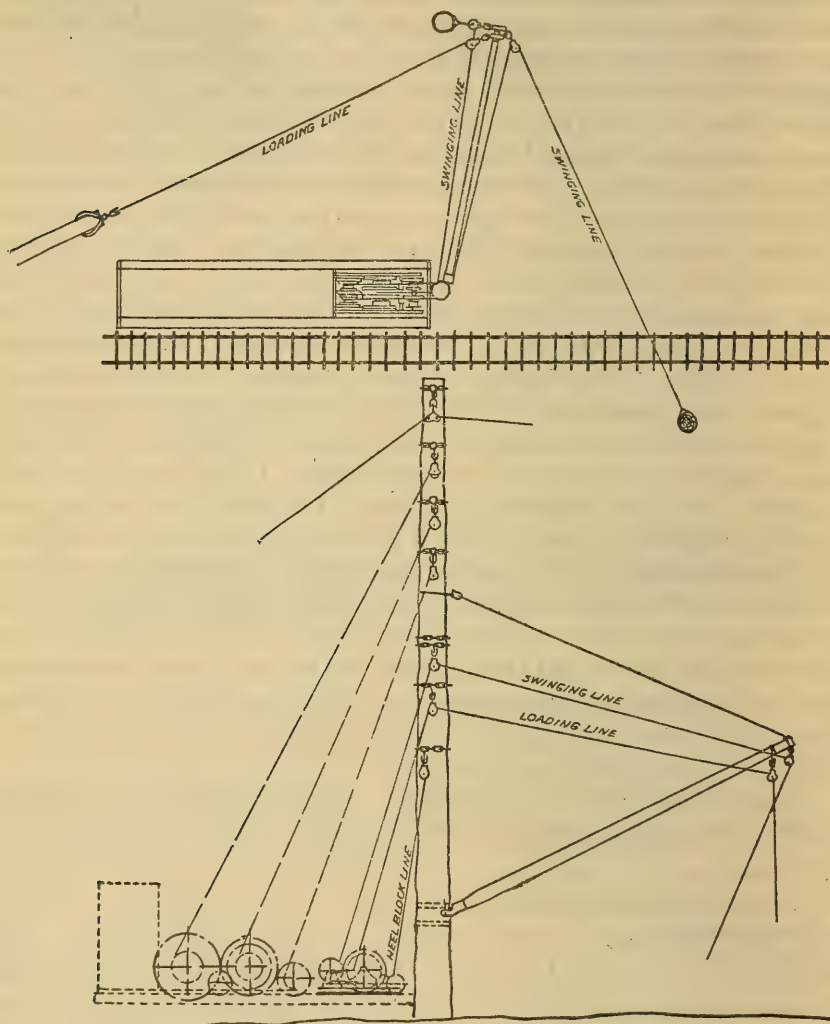


FIG. 67.—Swinging-boom loading system.

line loading method. To remedy this defect some operators are using a swinging boom of the type shown in figure 67.

The boom is about 50 feet long and made of a 16 by 16 inch timber, tapered down to 12 by 12 inches at each end. The end that is attached to the head spar tree is stepped on the under side, and has a hole about 1 inch larger than the pin. It is fastened to the tree by two 2-inch eye bolts.

This method is used in connection with a six-drum loading engine. One of the two drums nearest the spar tree carries the heel block or tightening-up line; the other, the transfer line. One of the two large middle drums carries the loading line; the other, the train or "spotting line." The other two drums carry the swinging lines. The efficiency of the whole device depends largely on the proper rigging and handling of the last-mentioned line. When loading is being done from the left side, the line from the left swinging drum should lead through a deep sheaved block attached to the left side of the spar tree and somewhat above the peak of the boom, thence to a block attached to the left side of the outer end of the boom, and thence to a stump opposite the swinging drum and from 40 to 60 feet from the engine. The opposite line is rigged in a similar manner.

It is claimed that this rig will load logs averaging 700 feet in volume at the rate of one per minute or minute and a half, and that it is especially valuable for loading from steep ground.

EQUIPMENT.

LOADING ENGINES.

The power used in loading may be furnished by a loading drum on the yarding or roading engine, or by a separate loading engine. In times past it was the universal practice to use a spool or loading drum on the yarding or roading engine; that is, when power machinery was used in loading. For several years, however, a number of operators have used a separate engine in loading. With the single gin-pole loading method, it is difficult to load the logs as fast as they are yarded when the power is furnished by a loading drum on the yarding engine, or at least in such a way and at such times as not to interfere with the yarding work. The use of a separate loading engine is thought to be safer, since the engineer has only the loading to occupy his attention. It is not possible to use the loading drum on a yarding engine with overhead loading engines.

The cylinders of loading engines range in size from $6\frac{1}{2}$ by 8 inches to $9\frac{1}{2}$ by 10 inches. The engines are built with one, two, three, or four drums. On most types there is a gypsy on the extended drum shaft. All loading engines have steel frames, high or double high pressure boilers, and liberal friction drums with brakes, pawls, etc.

The single-drum engine is adapted for use with the single gin-pole loading method. The double-drum engine is designed for use with overhead loading methods that do not require a standing line. The three-drum engine is used to operate the same sort of overhead system. When the third drum is not needed for loading purposes, it may be employed to good advantage in switching and spotting cars. The four-drum engine is adapted for operating a system of loading that uses a standing line upon which a carriage travels.

In connection with the following discussion of prices and weights, the sizes of most of the loading engines used in the region are given. It will be noted that there is no great range of sizes. The larger sizes are, of course, used in loading the larger timber. The tendency of the industry is to use large loading engines. The sizes used in connection with different loading methods are suggested under "Methods."

The selling prices of loading engines are given in Table 23. The prices are those of March, 1916, and it can not be said that they are more than substantially correct for that time, since they were furnished by manufacturers to be used in this publication and not for the purpose of trading. The prices are on standard engines and do not include any special parts.

TABLE 23.—*Sizes, weight, and prices of loading engines.*

Size.	Type.	Capacity of drums.	Size and working pressure of boilers.	Speed of lines.	Weight.	Selling price f. o. b. Portland, Tacoma or Seattle.
<i>Inches.</i>				<i>Feet per minute.</i>	<i>Pounds.</i>	
6½ by 8	Twin-drum.	500 feet ¾-inch line.....	36 by 84 inches high, 150 working pressure.	275	4,300	\$1, 125
6½ by 9	Double-drum.	780 feet ¾-inch line.....	36 by 84 inches high, 150 working pressure.	Lower, 300	} 9, 100	1, 240
		Upper, 1,050 feet ¾-inch line.....	36 by 84 inches high, 150 working pressure.	Upper, 425		
7 by 10	Single-drum.	1,650 feet ¾-inch line.....	42 by 84 inches high, 150 working pressure.	270	8, 100	1, 295
7 by 10	Single-drum.	2,340 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	400	11,000	1, 250
7 by 10	Double-drum.	2,580 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	400	11,000	1, 250
7 by 10	Three-drum.	Main, 2,580 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	Main, 340	} 14, 800	1, 625
		Trip, 2,580 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	Trip, 400		
7 by 10	Three-drum.	Main, 2,580 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	Main, 400	} 16, 400	1, 800
		Trip, 1,480 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	Trip, 400		
7 by 10	Four-drum.	Main upper, 1,480 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	400	} 17, 500	1, 900
		Trip upper, 1,480 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	400		
		Main lower, 1,480 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	400		
		Trip lower, 1,480 feet ¾-inch line.....	44 by 106 inches high, 175 working pressure.	400		
7½ by 10	Three-drum.	Main, 1,200 feet ¾-inch line.....	42 by 84 inches high, 150 working pressure.	Main, 293	} 11,000	1, 745
		Trip, 350 feet ¾-inch line.....	42 by 84 inches high, 150 working pressure.	Trip, 383		
9 by 10	Three-drum.	Main, 1,740 feet ¾-inch line.....	48 by 103 inches high, 175 working pressure.	Main, 376	} 25, 500	2, 825
		Lower, 830 feet ¾-inch line.....	48 by 103 inches high, 175 working pressure.	Lower, 470		
9½ by 10	Three-drum.	Main, 1,100 feet 1-inch line.....	50 by 120 inches high, 175 working pressure.	Main, 370	} 24,000	2, 675
		Trip, 1,890 feet ¾-inch line.....	50 by 120 inches high, 175 working pressure.	Trip, 440		
		Car drum, 1,180 feet ¾-inch line.....		Car, 440		

It was pointed out in the discussion of yarding that some operators use an extra yarding engine for the purpose of reducing the time lost in moving from one setting to another. This means that such operators have an extra loading engine also if the power used in loading is furnished by a separate loading engine.

LOADING ENGINE REPAIR PARTS AND MATERIALS.

For the purpose of a timber appraisal the fixed investment in loading engine repair parts and materials in connection with one engine may be placed at about \$75.

SPARK ARRESTERS, WATER TANKS, SLEDS.

The selling prices of spark arresters are given under the heading "Ground yarding." Steel tanks adapted for use in connection with loading engines cost about \$100. Loading engine sleds cost about \$200 and last from three to four years. Spark arresters, water tanks, and sleds are discussed under the heading "Ground yarding."

OIL-BURNER EQUIPMENT.

The approximate cost of the equipment used in burning crude oil on loading engines amounts to \$375. This price includes the tank on the rear end of the sled, which is used for the storage of both oil and water. The cost of the maintenance of this equipment amounts to about \$25 per year.

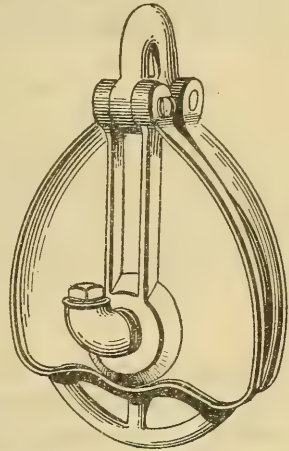


FIG. 68.—Loading block.

BLOCKS.

Only such blocks as are used in loading are taken up here. Some of the blocks listed under this heading, however, are used in overhead and high-lead yarding.

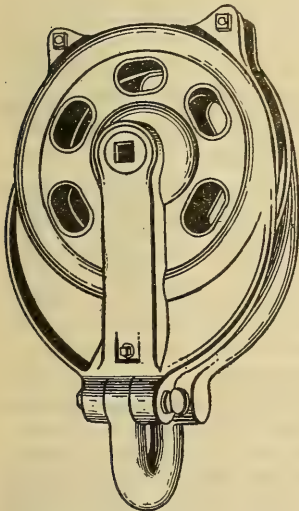


FIG. 69.—Overhead block.

Figures 68 and 69 show two of the types of loading blocks. Several other types are used. The proper size of blocks was discussed in a general way under the heading "Ground yarding." The size to be used with different methods of loading is suggested in the discussion headed "Methods."

The cost of loading blocks varies because of difference in the type, size, and make, and because different materials are used in their construction. The following gives the weight, size, and selling price of two types of loading blocks, f. o. b. Portland in March, 1916. It should be borne in mind that blocks are manufactured by several companies and that they can no doubt be purchased as satisfactorily at Tacoma, Seattle, and other points as at Portland.

	Net price.
No. 1 sheaves, 12 by 1½ inch manganese steel.....	\$18
No. 2 sheaves, 14 by 1½ inch manganese steel.....	22

This block is adapted for gin-pole or overhead loading.

The blocks listed below are adapted for any work where blocks are hung in an overhead position and frequent oiling is impossible without great loss of time. They are of the auto-lubricating type. The sheaves are made of manganese steel.

Prices of blocks.

No.	Sheave.	Bearing.	Diameter pin.	Weight.	Net price.
	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	
1.....	12 by 2	3	2½	115	\$27.00
2.....	14 by 2	3	2½	150	34.00
3.....	18 by 2½	4½	3	230	50.00
4.....	24 by 3	5	3½	410	81.00
5.....	24 by 5	7	3½	450	90.00
6.....	36 by 3	8	3½	750	144.00

TREE JACK.

Figure 46 is a cut of one of the types of tree jacks. They are designed for extremely heavy duty, such as is found in overhead loading and yarding. They are easy on the lines, since the strain is equally divided on the three sheaves, the same results being secured as with an extremely large sheave. The size and net selling prices f. o. b. Portland, Tacoma, or Seattle in March, 1916, were as follows:

Tree jacks.

No.	Size of sheaves.	Net selling price with manganese-steel sheaves.
	<i>Inches.</i>	
1.....	10 by 3	\$67.50
2.....	14 by 3	78.75
3.....	16 by 3	90.00
4.....	9 by 7	82.50
5.....	14 by 6½	93.75
6.....	16 by 9	114.00

Spares.

Item.	Net price.					
	No. 1.	No. 2.	No. 3.	No. 4.	No. 5.	No. 6.
Pair forged sides.....	\$22.50	\$25.50	\$27.00	\$22.50	\$25.50	\$27.00
Bronze bushed manganese-steel sheaves.....	9.75	13.50	15.00	15.00	18.00	24.00
Shackle and pin.....	5.25	6.00	6.00	5.25	6.30	6.80
Set of three pins.....	6.80	6.80	7.30	6.80	8.00	9.00
Bronze bushing.....	2.65	2.65	2.65	3.40	3.75	5.25

LOADING LINES.

The selling price of wire rope is discussed under "Ground yarding." The length and size of lines used are dealt with under "Methods" in this section.

MISCELLANEOUS EQUIPMENT.

In addition to the equipment listed above, some small equipment is necessary in connection with loading, such as hooks, tongs, slings, straps, splicing tools, links, engine repair tools, clevises, etc. The fixed investment in such equipments amounts to about \$100 per loading engine.

COST.

The cost of loading consists, in a general way, of operating labor, improvements, depreciation on loading engines, maintenance or replacement of lines, blocks, etc., and supplies. Some operators consider it advisable to charge a portion of certain more or less fixed costs, such as the salaries of foreman, bookkeeper, timekeeper, etc., to loading.

OPERATING LABOR.

The operating labor constitutes the heaviest item of expense. It is this item which generally finds its way into cost statements of operators under the heading "Loading." Needless to say such a segregation is misleading unless one is familiar with the practice.

The total cost of a loading crew per day depends on the method used and the rate of pay. If the power is furnished by a spool on the yarding or roading engine, the loading crew is usually considered as being made up of a head loader, second loader, and spool tender. In theory, a part of the labor cost of the fireman and wood buck, necessary adjuncts of the yarding or roading crew, should be charged to loading. If the power is furnished by a separate loading engine, the loading crew consists of a head loader, second loader, engineer, and fireman. Of course, if oil is used as fuel in the loading engine, the services of a fireman are generally dispensed with.

The following list is intended to approximate the average wages paid to members of the loading crew during the past six years. The wages designated "High" and "Low" do not represent extremes, but an average of high and low wages.

Wages of loading crew.

Position.	Average.	High.	Low.
Head loader.....	\$4.25	\$4.75	\$3.50
Second loader.....	3.50	3.75	3.25
Gipsy, or loading-drum, tender.....	3.25	3.50	2.75
Loading engineer.....	3.25	3.50	3.00
Loading fireman.....	2.50	2.75	2.25

While this list of wages is substantially correct, taking it straight through the industry, it is to some extent misleading. Head loaders, where the output is large, are not infrequently paid \$5 or more per day during what might be called normal times. Then, the engineer,

or lever man, used in connection with the guy-line loading method, is sometimes paid as high as \$5 per day. The success of this loading method depends largely on the skill of the lever man, and the number of really skillful lever men of this class is limited.

The cost per thousand feet of operating labor depends to a great extent on the output. The method used and the wages paid also influence this cost. The total labor cost per day of a loading crew, however, is to a great extent fixed. A certain crew has to be employed regardless of the output, and it follows that the operating-labor cost per thousand feet will be high or low in large measure as the output is high or low. This is illustrated in Table 24 and accompanying discussion.

TABLE 24.—*Operating labor cost per thousand feet for loading.*

Case.	Time.	Year.	Cost per thousand feet.	Location.
1.....	1 year.....	1912	\$0.217	Columbia River district, Oregon.
2.....	do.....	1912	.112	Columbia River district, Washington.
3.....	do.....	1911	.152	
		1912	.247	Do.

Case 1.—The method of loading is shown in Figure 61. The output per day averaged about 67,000 feet. The timber was small, the logs averaging about 600 feet in volume. The crew and daily wages were as follows: Engineer, \$3.50; fireman, \$2.50; head loader, \$5; second loader, \$3.75.

Case 2.—The method of loading is shown in Figure 61. The output per day averaged about 71,000 feet. The timber was large, the logs averaging about 1,900 feet in volume. At times the logs contained six, seven, or eight thousand feet, necessitating the use of slings instead of hooks, also the transference of the tail hold from the gin pole to the load. The crew and daily wages in 1912 were as follows: engineer, \$3.25; fireman, \$2.75; head loader, \$3.75; second loader, \$3.25 to \$3.50. During part of this year oil was used as fuel, making a fireman unnecessary. Then at times it was not necessary to employ a second loader, the regular chaser of the yarding crew doing the work which is ordinarily done by a second loader. The output in 1911 averaged about 75,000 feet per day.

Case 3.—The method of loading was the same as that used in the previous case. The average output per loading day was about 57,000 feet, the logs averaging about 600 feet in volume. The crew and daily wages were as follows: head loader, \$4; second loader, \$3.50; engineer, \$3.25; fireman, \$2.75.

LANDINGS.

As a general thing the cost of landings per thousand feet is not classified in cost statements of logging operators, being included in the cost of either yarding or loading. Sometimes, of course, the cost of yarding and loading is segregated under one heading, the cost of landings being included in the cost of this combined step. Many operators, however, keep a landing account.

Landings are necessary with ground yarding and with some systems of loading. In the past landings were more of a factor in loading than now, which resulted in landings being associated with loading rather than yarding, and this association still continues.

In collecting and analyzing data dealing with the cost of landings care has to be exercised to determine what is included in the cost. It may include only the labor cost, or it may include the labor, ma-

terial, and supply costs, also a rental on the equipment used in their construction. In addition to the cost of the landings proper, it may include the cost of raising gin poles, swinging rigging on gin poles, a part or all of the extended water system, and digging engine settings. These costs are handled differently by different companies.

The cost of landings per thousand feet of output varies with the type of landing, the character of the country, the number of landings per section, and the average stand per acre. The landings used with ground yarding are more elaborate than those used with high-lead or overhead yarding, especially in steep country, where considerable cribwork has to be done. The labor cost probably ranges between \$50 and \$300; in most cases from \$75 to \$150. The cost of landings in specific cases is given in Table 25 and accompanying discussions:

TABLE 25.—*Comparative costs of landings in specific cases.*

Case.	Number of landings.	Region.	Year.	Type.	Average cost. ¹
1.....	29	Columbia River.....	1912	Fig. 64....	\$155.00
2.....	100	Columbia River.....	1913	Fig. 64....	135.00
3.....	75	West foothills, Cascades.....	1912	Fig. 72....	100.00
4.....	8	Columbia River.....	1912	Fig. 64....	208.00
5.....	8	Columbia River.....	1912	Fig. 64....	130.00
6.....	30	Flat, west Cascades.....	1912	Fig. 72....	\$50.00-70.00
7.....	14	West slope, Cascades.....	1912	Fig. 72....	95.00-175.00
8.....	15	Columbia River.....	1912	Fig. 72....	285.00-340.00

¹ In no case does the cost include the timber used in the landings.

Case 1.—The cost includes the labor used in clearing sites, building landings, raising gin poles, swinging loading rigging, digging engine settings (yarding and loading), etc., in fact, everything except the moving of the yarding and loading engines. The country was practically level.

Case 2.—The cost is based on the landings constructed at three camps, representing a great variety of conditions, and includes the same items of expense as in the previous case.

Case 3.—The cost includes the labor and supplies used in building the landings and raising gin poles, the landings for the most part being constructed on relatively level ground.

Case 4.—The cost includes the same items of expense as in the first case, the landings being constructed in a mountainous country with a great variety of conditions.

Case 5.—Same as previous case.

Case 6.—The cost includes the labor used in constructing landings on practically level ground.

Case 7.—The cost includes the same items of expense as in the previous case, the landings being constructed on sidehill country. Six were constructed on the lower sides of the track at an average labor cost of \$175; eight on the upper side, at an average labor cost of \$95. Those on the lower side of the track contained 7,500 feet of timber on the average; those on the upper, 3,500 feet.

Case 8.—The cost includes the labor used in building the landings, for the most part on sidehill country. The following shows the crew and wages paid per day:

Hook tender.....	\$4.50
2 rigging slingers.....	6.50
1 rigging slinger.....	3.00
Engineer.....	3.25
Fireman.....	2.75
Total per day.....	20.00

The number of landings depends on the character of the country. They are located along the spur railroads, and as the mileage of spur railroads per section increases the number of landings per section in-

creases. Putting it another way, the number of landings increases as the maximum transportation distance from the stump to the landings decreases. More landings are necessary where all the timber is yarded direct to the track than where a part of it is swung or roaded, especially where a large part of the timber finds its way to the landings over pole roads. The distance between landings on the same side of the track depends on the chance and what the management thinks is proper. At one camp, where the ground was practically level, the landings on one side of the spur tracks were about 850 feet apart; at another, where conditions were practically the same, they were not more than 700 feet apart. It would seem that they should never be farther apart than 1,300 feet. One company operating in relatively level country is building about 50 landings per section; another, working in much the same character of country 24 per section; still another, working in mountainous country, where the logs have to be transported long distances by logging engines, 6 per section.

The cost of landings per thousand feet is greater in light stands of timber than in heavy stands. While fewer landings are built under the former conditions than under the latter, the reduction in the total cost because of this is not sufficient to offset the effect of the average stand per acre. Table 26 and accompanying discussion give the cost of landings per thousand feet at four camps.

TABLE 26.—*Comparative cost of landings per thousand feet.*

Case.	Time based on—	Year.	Cost per thousand feet.	Location.
1	1 year.....	1912	\$0.09	Along the Columbia River, Oreg.
2	1 year.....	1913	.09	Do.
2	1 year.....	1912	.03	
3	1 year.....	1912	.085	Do.
4	1 year.....	1912	.08	Flat west of Cascades.

Case 1.—The cost includes the labor used in clearing sites, building landings, raising gin poles, swinging loading rigging on gin poles, digging engine settings, etc., in fact, everything except the moving of yarding and loading engines. Landings of the type shown in figure 61 were used. The country was practically level.

Case 2.—The cost includes the same items of expense as in the previous case. In 1913, because of the character of the country, a larger number of landings were constructed, which is largely responsible for a higher cost than in 1912. The country logged in 1912 was very mountainous.

Case 3.—The cost includes the same items of expense as in the first case. Landings of the type shown in figure 64 were used. Some of the timber was double hauled.

Case 4.—The cost includes the labor used in constructing landings of the type shown in figure 60. All the timber was single hauled.

As a rule landings are constructed by the same crew that clears the right of way for the spur railroads. Table 27, which shows the cost of three landings, indicates the division of labor, also the character of work. It will also serve to indicate how the cost of landings can vary because of what is included.

TABLE 27.—Detailed cost of landings.

Class of labor.	Case 1.			Case 2.			Case 3.		
	Num-ber of hours.	Rate per hour.	Total cost.	Num-ber of hours.	Rate per hour.	Total cost.	Num-ber of hours.	Rate per hour.	Total cost.
Hooktender.....	78	\$0.425	\$33.15	20	\$0.475	\$9.50	37	\$0.425	\$15.72
Rigging men.....	108	.32	34.56	40	.325	13.00	56	.32	17.92
Signalman.....	78	.25	7.50	20	.25	5.00	37	.25	9.25
Engineer.....	58	.40	23.20	20	.40	8.00	37	.325	12.02
Fireman.....	78	.30	23.40	20	.30	6.00	37	.30	11.00
Wood buck.....	78	.25	19.50	20	.25	5.00	37	.25	9.25
Common labor.....	290	.25	72.50	100	.25	25.00	27	.275	7.42
Labor: Swamping, digging engine settings, and building landings.....			213.81			71.50			82.58
Labor: water system.....			25.80			24.00			
Total labor.....			239.61			95.50			82.58
Powder.....			8.25			5.00			4.50
Rental on engines.....			117.00			30.00			55.50
Total cost.....			364.86			130.50			142.58

Case 1.—The cost includes the clearing of site, yarding of the material, excavating for brow skids, etc., preparing and raising gin poles, swinging loading rigging on poles, digging settings for yarding and loading engines, as well as building the landing proper. The common labor in this case, as well as in the other two, did the pick-and-shovel work and such swamping as could be done by hand.

Case 2.—The cost includes the same items of expense as the previous case, except that it does not include the cost of preparing and raising the gin pole and the swinging of the loading rigging.

Case 3.—With the exception of the water system, this case includes the same items of expense as Case 2.

Generally speaking, the same equipment is used in building landings as in yarding, viz., a steam yarding engine, lines, blocks, chokers, etc.

One company has used a gasoline logging engine successfully for two years in building landings. It resembles the steam logging engine in a general way, and is a 40-horsepower two-cylinder, opposed type of engine. The combination of gears, drum, and frictions yields a high tractive efficiency, and gives, it is claimed, an engine that is capable of withstanding hard service. The drums and gears are erected on a built-up steel frame. The engine and 200-gallon water tank are independent of the drum mechanism, and are bolted securely to the sled. The power is transmitted by a No. 78 Griplock steel chain drive about 8 feet long, running from a 12-inch sprocket on the engine to an 18-inch sprocket on the countershaft, the latter being fitted with a 9-inch pinion. The engine has three drums, the frictions being such as to require very little pressure to hold the heaviest strain. It weighs about 7 tons, and is mounted on a sled 32 feet long and 4½ feet wide. A compressed-air tank, charged from the cylinders, furnishes about 50 pounds pressure for the operation of the signal whistle. The main drum carries 1,500 feet of ¾-inch line; the trip drum, 3,000 feet of ½-inch line; the loading drum, 300 feet of ⅝-inch line. The main yarding line can be made to travel 500 feet per minute; the trip line, 800 feet per minute. The cost of fuel has been approximated at \$2.70 per 10-hour day, consisting of

from 12 to 15 gallons of gasoline at a cost of 17 or 18 cents per gallon delivered at the engine. From 10 to 15 gallons of water are consumed per day.

This type of engine is also used at one camp for yarding timber suitable for piling and boom sticks from areas that have been logged once. Yarding is successfully done at a distance of from 1,000 to 1,500 feet. Three boom sticks, with 22-inch tops and 80 feet in length, can readily be handled at a trip. It is especially adapted for clearing rights of way and stump land, also pile-driver work. It was primarily designed for clearing stump land, for which purpose about 50 are in use. Engines of a smaller horsepower can be secured.

WIRE ROPE.

The cost of wire rope per thousand feet of loading output is dealt with in a general way under "Ground yarding." Ordinarily, the amount is small. With the single gin-pole loading method, the cost of the main loading and spotting lines per thousand feet is about \$0.01. In the case of an overhead loading method, where no standing line is used, the cost of the main and trip loading lines and the spotting line per thousand feet is about \$0.03. Where a standing line loading method is used, the cost of the loading and spotting lines per thousand feet ranges from \$0.03 to \$0.06, depending on the distance between the spar trees.

BLOCKS, HOOKS, TONGS, CARRIAGES, AND OTHER MISCELLANEOUS LOADING EQUIPMENT.

The maintenance and replacement cost of blocks, hooks, tongs, carriages, and other miscellaneous equipment per thousand feet depends on the loading method used. It ranges from \$0.01 to \$0.03.

FUEL.

The cost of fuel for logging engines is discussed in a general way under "Ground yarding." A loading engine burns between six and seven hundred feet of wood, or about four barrels of fuel oil per day.

LUBRICANTS.

The cost of lubricants used in loading is about \$0.006 per thousand feet of output.

MAINTENANCE.

The maintenance of a loading engine costs about \$150 per year, this amount being about equally divided between labor and new parts, material, etc.

DEPRECIATION.

The Forest Service in connection with timber-appraisal work has placed the life of loading engines at eight years, and has assumed that the engines at the end of that time will be worth about 10 per cent of the initial cost. The depreciation on a loading engine that cost \$2,700, together with the fuel-oil-burner equipment, water and oil tank, sled, etc., amounts to about \$425 per year, or about \$0.035 per thousand feet.

RAILROAD TRANSPORTATION.

The bulk of the timber logged in the region is conveyed over standard-gauge railroads to the mills or large bodies of water for distances ranging from a mile or two to 30 miles or more. The entire length of line may be owned by the logging operator, or the logging road only be used to deliver the logs to some point on a common-carrier railroad.

Bryant, in "Logging," states that the successful use of steel-rail logging roads began in 1876. The number of logging railroads increased rapidly, and by 1881 there were 71 in operation in Michigan and 5 in Wisconsin. The first on the Pacific coast was operated about 1885. Railroad transportation was used on the coast practically as soon as the length of haul made it the most economical method, so that it did not have to supplant other methods, except in a few cases. Now it is the preferred form of transportation, the Grays Harbor and Willapa Harbor districts being the only ones where it is not exclusively used.

Railroads have made accessible large bodies of timber which otherwise could not be logged, since the conditions in the region, for the most part, are not favorable for driving. This mode of transportation has several other advantages over other forms. The logging operator does not have to wait for flood waters to float the logs to the mill or market, to anticipate market conditions in advance, to have large sums of money tied up along the banks of streams, or to lose logs in transit. Furthermore, the railroad delivers clean logs to the mill, which results in an appreciable saving in cost of manufacture.

COMMON-CARRIER RAILROADS.

While some of the long hauls are made over railroads owned entirely by the logging companies or closely affiliated companies, most of them are made over common-carrier railroads.

RATES.

In Table 28 is given a list of specially quoted log rates charged by common-carrier railroads in Oregon and Washington in 1913.

TABLE 28.—*Freight tariffs on logs in 1913.*

Name of railroad.	Hauling distance.			Established rates on logs per 1,000 feet between points involving a haul of—							Remarks.
	Miles.	Shipping point.	Delivery point.	Less than 20 miles.	20-30 miles.	30-40 miles.	40-50 miles.	50-60 miles.	60-70 miles.	70-80 miles.	
Northern Pacific Railway Co.	4	Crescent, Wash.	Sumas, Wash.	\$0.60							Minimum charge, \$6 per car.
Do.	22	Acme, Wash.	Bellingham, Wash.		\$1.40						Minimum, 7,000 per car.
Do.	67	Wickersham, Wash.	Everett, Wash.				\$1.25	\$1.85			Do.
Do.	48	Hazel, Wash.	do.								20 or more cars; 7,000 per car, minimum.
Do.	41	Oso, Wash.	do.				1.60			\$1.90	
Do.	72	do.	Freemont, Wash.								
Do.	45	Fortson, Wash.	Everett, Wash.				1.60				15 or more cars; 7,000 per car, minimum.
Do.	15	Bordeaux, Wash.	Olympia, Wash.	.90							Do.
Do.	28	Porter, Wash.	Aberdeen, Wash.		1.25						10 or more cars; 7,000 per car minimum.
Do.	22	Elma, Wash.	do.		1.00						Do.
Do.	17	Satsop, Wash.	do.	1.25							Do.
Do.	13	Tulips, Wash.	Hoquiam, Wash.	1.25		\$1.25					Do.
Do.	30	Lytle, Wash.	do.			1.25					Do.
Do.	30	Porter, Wash.	do.								
Do.	18	Francis, Wash.	Raymond, Wash.	1.35							
Do.	35	Pilchuck, Wash.	Everett, Wash.			1.55					
Do.	45	Yacolt, Wash.	Felida, Wash.				1.00				15 or more cars; 6,000 per car, minimum.
Do.	38	Easton, Wash.	Ellensburg, Wash.			1.55					
Do.	49	Stampede, Wash.	do.				1.65				
Do.	20	Wickersham, Wash.	Bellingham, Wash.		1.40						
Do.	17	Globe, Wash.	Raymond, Wash.	1.35							
Do.	32	Robe, Wash.	Everett, Wash.			1.50					
Do.	14	Wingate, Wash.	Puyallup, Wash.	1.25							
Do.	18	Orting, Wash.	Tacoma, Wash.	1.00							10 or more cars; 7,000 per car, minimum.
Do.	10	Weatherwax, Wash.	Aberdeen, Wash.	.60							Minimum, 7,000 per car.
Do.	14	do.	Hoquiam, Wash.	1.00							Do.
Do.	29	Spiketon, Wash.	Tacoma, Wash.		1.10						Single cars, \$1.25 per 1,000; 10 or more cars, \$1.10.
Do.	63	Bunker, Wash.	Aberdeen, Wash.						1.65		

Chicago, Milwaukee & Puget Sound Railway Co.	25	Duvall, Wash.	Everett, Wash.	1.00				Less than 10 cars, \$1.25 per 1,000.
Do.	25	Maple Valley, Wash.	Seattle, Wash.	1.40				Minimum, 7,000 per car.
Do.	19	S. Elma, Wash.	S. Aberdeen, Wash.	1.10				10 or more cars, \$1.10 per 1,000; single cars, \$1.40, minimum, 7,000.
(Tacoma & Eastern)	25	Tidewater, Wash.	Tacoma, Wash.	1.00				Single cars, minimum, 5,000 per car.
Do.	10	Ashford, Wash.	Mineral, Wash.	.60				Minimum, 6,000 per car.
Do.	65	Lindberg, Wash.	Tacoma, Wash.				1.40	Single cars, minimum, 6,000 per car.
Do.	45	Reliance, Wash.	do.			1.20		Do.
Do.	19	Morton, Wash.	Elbe, Wash.					Do.
Do.	45	Lindberg, Wash.	Kapowsin, Wash.	.80		1.20		Do.
Southern Pacific Railway Co.	13	Rector, Oreg.	Wheeler, Oreg.	1.10				
(Pacific R. R. & Navigation Branch).	59	Timber, Oreg.	Newberg, Oreg.				\$2.25	Minimum, 6,000 per car, 1 car or more.
Do.	18	Marcola, Oreg.	Eugene, Oreg.	1.75				
Southern Pacific Railway Co.	20	Falls City, Oreg.	West Salem, Oreg.	1.50				
Southern Pacific Railway Co. (Falls City & Western Branch).	14	Black Rock, Oreg.	Dallas, Oreg.	1.00				
Do.	10	Greenburg, Oreg.	Falls City, Oreg.	1.00				
Great Northern Railway Co.	13	Sultan Crossing, Wash.	Sheltonish, Wash.	.90				Minimum, 6,000 per car.

At the time the above rates were in effect, the Northern Pacific Railroad Co. quoted distance rates as follows, the special rates mentioned above to be applied when less than the distance rates. These distance rates deal with all main and branch line stations in the State of Washington west of and including Ellensburg, Wash., except the haul between Granite Falls and Robe, Wash., on the Monte Cristo Branch.

TABLE 29.—*Distance, freight tariffs.*

[Minimum, 7,000 feet per car.]

Distance.	Rate in dollars per 1,000 feet.
10 miles or less.....	\$1. 00
Over 10 miles and not over 15 miles.....	1. 25
Over 15 miles and not over 20 miles.....	1. 35
Over 20 miles and not over 25 miles.....	1. 40
Over 25 miles and not over 30 miles.....	1. 45
Over 30 miles and not over 35 miles.....	1. 50
Over 35 miles and not over 40 miles.....	1. 55
Over 40 miles and not over 45 miles.....	1. 60
Over 45 miles and not over 50 miles.....	1. 65
Over 50 miles and not over 55 miles.....	1. 70
Over 55 miles and not over 60 miles.....	1. 75
Over 60 miles and not over 65 miles.....	1. 80
Over 65 miles and not over 70 miles.....	1. 85
Over 70 miles and not over 75 miles.....	1. 90
Over 75 miles and not over 80 miles.....	1. 95
Over 80 miles and not over 85 miles.....	2. 00
Over 85 miles and not over 90 miles.....	2. 05
Over 90 miles and not over 95 miles.....	2. 10
Over 95 miles and not over 100 miles.....	2. 10
Over 100 miles and not over 110 miles.....	2. 15
Over 110 miles and not over 120 miles.....	2. 20
Over 120 miles and not over 130 miles.....	2. 25
Over 130 miles and not over 140 miles.....	2. 30
Over 140 miles and not over 150 miles.....	2. 35

It should be noted in connection with the special rates that the rates depend on the amount shipped; also that the rates are applied in connection with a carload minimum. In a specific case it is easy to measure the effect of the former, while the latter is difficult to get at. If the logs are large and sound, the latter will have the effect of increasing the quoted rate but little, if any. Where the logs are small and extreme care is not used in loading, the actual rate per thousand feet may be 10 or 15 per cent higher than the quoted rate. One company, operating in small second-growth timber and paying a quoted rate of \$1 per thousand feet, found at the end of a year that they had actually paid \$1.15 per thousand feet, the increase being due to the fact that a large number of the cars did not contain the

minimum carload established by the railway company. The next year this company, through more careful loading, kept the actual rate equal to the quoted rate. This was not easy, however. The logging superintendent found that the loaders did not see or appreciate the effect of underloads on the actual rate and in turn on the cost of logging. The mere telling the loaders to be sure to put the minimum carload on a car did not remedy the evil, neither did discharging the loaders. It was only when the superintendent, with the scaler, worked with the loaders, pointing out the underloads on the ground and demonstrating by mathematics the increased cost of transportation per thousand feet because of specific underloads, that the evil of the underload was gotten away from.

As a rule, logging operators pay for log transportation on the basis of the railroad company's scale. This scale in most cases approaches a gross scale, while the logging operator sells his logs and estimates his logging cost on the basis of a net scale. Where the logs are sound, the difference between the quoted and actual rate is small. In some cases, however, the difference amounts to considerable. One operator, shipping on a quoted rate of \$1.25 per thousand feet, found that the cost actually amounted to \$1.55; another company, shipping on a quoted rate of \$1.50 per thousand feet, actually paid \$1.85 per thousand feet.

LOGGING RAILROADS.

LOCATION.

The locating of the main-line railroad and primary spurs is the most important step in the logging operation. Failure to open up a tract of timber at the right point may spell failure. Mistakes in connection with other steps can be corrected. It is not so in the case of the railroad location.

In general the location and character of a logging railroad depend on the amount of timber it is to handle and the time it is to be operated. The longer any railroad is to be used and the heavier the traffic, the better it should be constructed. In any case, the cost of construction should be the smallest amount consistent with reasonable operating and maintenance costs. Logging railroads are invariably constructed more cheaply than even branch trunk lines, a shorter operating period making heavier grades, sharper curves, and a poor roadbed practical. The amount of traffic that is to pass over the main line and each of the spurs, the total rise and fall which must be overcome (as indicated by a topographic map or a careful reconnaissance), and the speed with which the timber is to be removed are guiding factors in deciding on the character of roadbed that should be built and the kind and amount of motive power that should be used.

Topography largely fixes the locations, but the general plan of logging determines whether the railroad lines, especially the spurs, shall follow valleys, ridge faces, or the tops of ridges. Spurs are generally constructed wherever necessary to bring the timber within economic yarding, swinging, or roading distance of the track.

In most cases the main line enters the tract at the lowest point, following water grade wherever possible, since this location usually gives the best grade out of the region and permits the logs to be hauled down grade. Obviously, this is not possible in all cases, especially where the topography of the country is such that the spur railroads are laid on ridges and the timber yarded up grade. The shortest possible route, naturally, is selected, unless heavy cuts, fills, bridge work, and trestle work can be avoided by a longer line. Switchbacks are frequently used to overcome sharp changes in the grade. The same end may be gained more satisfactorily by doubling back with a curve. This latter method, however, often necessitates a heavier construction expense. Switchbacks often are the only practical means at hand for securing timber from elevations above or below the main line. When the rise in elevation is considerable, it may be advisable to put in an incline.

Under "Ground yarding," it was pointed out that where the ground is practically level the spur railroads are located so as to gridiron the tract, the distance between the spurs depending for the most part on the cost of the roadbed and the stand of timber per acre. Figures 16 and 17 show how the spur roads may be located in practice. In the first case the conditions from the standpoint of railroad construction approach the ideal. In the second case the ground conditions were harder than usual, which resulted in the timber being yarded and swung relatively long distances to the railroad. Spur railroads are located by the foreman or superintendent or by a logging engineer.

Grades and curvature.—The maximum grades and curvature allowed on any logging railroad vary with the character of the road and the type of locomotives used. Heavier loads must be hauled on the main lines than on the spurs, hence the grades and curvature must be lighter. If a geared locomotive is used, they may be heavier in either case since a geared locomotive can negotiate heavier grades and sharper curves than a rod engine.

The direction of the traffic and whether or not there are adverse grades must be considered in a discussion of grades and curvature. Traffic on logging railroads moves only one way, the general direction, as a rule, being down grade. Not infrequently, however, adverse grades are found on these roads, and they limit the number of cars that can be hauled at a trip. The effect of grade on the num-

ber of cars, unloaded and loaded, that can be hauled at a trip is illustrated in Table 30.

TABLE 30.¹—*Effect of grade on number of cars that can be hauled at a trip.*

TRAFFIC DOWN HILL.

Rate of grade (per cent).	Resistance in pounds per ton.	Weight of locomotive (tons).	Number of empty cars per train (uphill).	Capacity of train in feet board measure of logs (downhill).	Capacity of each car in feet board measure of logs.	Weight of empty cars (tons).
1	30	60	62	310,000	5,000	10
2	50	60	36	180,000	5,000	10
3	70	60	25	125,000	5,000	10
4	90	60	19	95,000	5,000	10
5	110	60	15	75,000	5,000	10

TRAFFIC UPHILL.

Rate of grade (per cent).	Resistance in pounds per ton.	Weight of locomotive (tons).	Number of loaded cars per train (uphill).	Capacity of train in feet board measure of logs (uphill).	Capacity of each car in feet board measure of logs.	Weight of loaded cars (tons).
1	26	60	19	95,000	5,000	27
2	46	60	14	70,000	5,000	27
3	66	60	9	45,000	5,000	27
4	86	60	7	35,000	5,000	27
5	106	60	5	25,000	5,000	27

¹ From The Timberman.

Except when topographic conditions forbid, long main-line logging railroads are usually constructed to permit the use of rod engines. When such engines are used, the grades should not exceed 3 or 4 per cent where empty cars are moved up grade and 1 per cent in the case of loaded cars; and the sharpest curves should not exceed 16 degrees. In the more mountainous region, the main lines can not be constructed for the use of rod engines except at a prohibitive cost, so that geared engines must be used. In such cases, the maximum grades do not ordinarily exceed 5 per cent when empty cars are to be hauled up them and 2 per cent in the case of loaded cars. The maximum curves used with a geared locomotive, as a rule, do not exceed 20 degrees.

Logging spurs are usually constructed for the use of geared engines, since the grades and curves on these lines must be heavier than those required on the main lines. Ordinarily, the maximum grade for empty cars is 7 or 8 per cent; for loaded cars, 3 or 4 per cent. Most operators try to keep the maximum curvature of the spurs down to 20 degrees, although in extreme cases the curvature may run as high as 50 degrees.

Methods of location.—The engineering steps preceding the building of logging railroads, while not always so clearly defined or performed in the same way, are in general the same as those preceding the construction of a common carrier railroad. They are (a) reconnaissance, (b) preliminary survey, and (c) location.

The reconnaissance in the case of main-line logging railroads consists of a more or less rapid examination of possible routes, with the following objects in view: To determine the most feasible and economical line between the timbered area and the delivery point; to locate the controlling points, which consist of stream crossings, summits of ridges, and other natural or artificial features of the territory through which the road must necessarily pass in order to make the largest amount of timber accessible; to determine the maximum grade and the maximum degree of curvature; to ascertain the kind of materials likely to be encountered in the construction of the road to determine the effect of the materials on the cost of maintenance; and to obtain a general idea of the approximate cost per mile of the completed road. This constitutes in the main the field work performed by a timber appraiser. From the information so secured, together with information usually secured by a preliminary survey, he must estimate the approximate cost of the main line.

For the purpose of determining relative elevations, maximum grades and curves, the directions of streams and roads, etc., the timber appraiser usually provides himself with an aneroid barometer, a pocket compass, and a hand level. With this equipment he personally investigates all important points involved and makes comprehensive notes of all topographic features along the route, such as the size and direction of streams, together with their high-water marks; the slope of important waterways that must be crossed; and any other information concerning them that can be secured. Such information as can be secured regarding the character of the soil and the prevalence of rock is carefully noted. In addition the appraiser notes the probable quantities of excavation, embankment, and bridging per mile; also any other data which will assist him in estimating the cost of the proposed railroad.

The method in the case of spur railroad is in large measure the same as that used for the main line, in that some one determines, after making an examination of the tract to be logged, the general routes of the main spurs.

Many operators in the region consider topographic maps an essential part of their equipment. These are prepared in connection with the timber cruise, or by engineers before the tract is opened up, the contour intervals ranging from 10 to 50 feet, depending on the

accuracy required and the roughness of the country. Such a map furnishes a basis for the preliminary location.

The reconnaissance of the main line having been completed and a route selected, the next thing is to make a preliminary survey of the main line for the following purposes: To determine the relative merits of alternative routes that have been examined on the reconnaissance; to obtain the necessary information for making a map and a profile of the route; to furnish data from which to project the location; to determine the approximate amount of work to be done in the matter of clearing, grading, and bridging; and to furnish data for an approximate estimate of the cost of all materials and labor required for the proposed road.

While most of the large companies employ a logging engineer to lay out their logging spurs, some have this work performed by the camp foremen. In the former case the engineer, in cooperation with the superintendent or foreman, roughly determines the routes of the spurs. This cooperation insures the maintenance of the proper balance between the railroad and the logging. The preliminary survey is then made. The engineer is aided by one or two rodmen and two or more axmen, depending on the density of the brush. As a rule, the engineer uses a transit on preliminary work, because of the accuracy demanded in the final results. The foreman generally uses a compass and a hand level of the Abney type.

The line is fitted to the ground in such a manner as to secure the best adjustment of the alignment and grade consistent with an economical cost of construction. If no topographic map is available, the work of location is done directly on the ground. In many cases, however, a contour map is prepared from the data secured by the preliminary survey, on which the location is projected.

Logging engineers may be employed by the month or year, at a salary ranging from \$100 to \$150 per month. In either case they may devote much of their time to mapping. In some cases engineers are used only on particularly difficult locations, being paid by the day. Arrangements are sometimes made whereby an engineer divides his time between two or more camps. The cost of engineering ranges from \$150 to \$400 per mile.

RIGHTS OF WAY.

Not infrequently logging railroads have to be built across the land of others. Under such conditions the land may be bought at private sale or it may be leased for a period sufficient to permit the removal of the timber. The second is the more satisfactory method, since a narrow strip of land is of little value to the owner, and it

is difficult to sell at the conclusion of a logging operation. Of course, if the road is ultimately to become a common carrier, the former would be desirable. Should a right of way be refused, a line can be forced across foreign holdings by condemnation proceedings and the payment of just compensation to the owner, the operator, however, forfeiting certain rights. For example, a logging operator acquiring a right of way by condemnation proceedings must agree to carry over such road any of the timber or other forest products of the lands through which such right of way passes, upon payment of a reasonable consideration, and failure to do so results in a forfeiture of the right of way.

CLEARING THE RIGHT OF WAY.

Before starting the grading of the right of way, it is necessary to cut and remove the standing timber, brush, and stumps which will interfere with the roadbed. This work is done by both contract and day labor. The right of way varies in width, seldom being wider than 50 feet. It is not possible to speak confidently of the cost of this work, since operators, as a rule, do not classify their accounts in such a way as to make it possible to secure data that are at all satisfactory. The average cost should not exceed \$500 per mile, where the stumps are blasted and the timber is dragged from the road with a logging engine. The following piecemeal data will serve to indicate the method of performing this work, also what the total cost consists of.

(a) In one case the cost of bucking the down timber on a mile of right of way ahead of the fallers amounted to \$55.

(b) The labor cost of felling the timber (13 trees) on 400 feet of right of way amounted to \$3.75. One of the fallers was paid \$4 per day, the other \$3.50. The diameters of the trees were as follows:

Number of trees (hemlock) :	Diameter in inches.
2 -----	16
2 -----	17
1 -----	18
1 -----	20
2 -----	24
1 -----	28
2 -----	30
1 -----	32
1 -----	60

(c) The cost of blowing 24 stumps on 600 feet of right of way amounted to \$40, as follows:

5 boxes of powder, at \$0.11 per pound -----	\$27.50
1 man, at \$3.50 per day -----	3.50
4 men, at \$2.25 per day -----	9.00
Total -----	40.00

The diameters of the stumps were as follows:

Number of stumps (hemlock) :	Diameter in inches.
7 -----	16
2 -----	17
4 -----	24
2 -----	32
2 -----	42
4 -----	48
3 -----	60

(d) The cost of blowing 8 stumps on 200 feet of right of way amounted to \$31.25, as follows:

5 boxes of powder, at \$0.11 per pound -----	\$27. 50
40 caps -----	. 55
50 feet of fuse -----	. 20
Labor -----	3. 25
Total -----	31. 50

This is at the rate of \$836 per mile. If, however, there were fills, all the stumps would not have to be blown out. The diameters of the stumps were as follows:

Number of stumps (hemlock) :	Diameter in inches.
2 -----	16
1 -----	17
1 -----	24
1 -----	32
1 -----	42
1 -----	48
1 -----	60

(e) The labor cost of swamping and blowing the stumps from 500 feet of right of way amounted to \$75.48. The cost of felling is not included in this, neither is the cost of moving the logging engine or extending the water system. Common labor dug the holes under the stumps and the chunking crew loaded and shot them. The size and wages of the chunking crew were as follows:

	Per day.
Hook tender -----	\$4. 50
Engineer -----	3. 50
Fireman -----	3. 00
Wood buck -----	2. 75
4 rigging men, at \$3.25 -----	13. 00
Total -----	26. 75

The common labor was paid \$2.75 per day.

(f) The labor cost of clearing 13,350 feet of right of way was \$2,454. This is at the rate of \$977 per mile. The stand of timber through which the right of way ran was cutting out about 50,000 feet per acre, consisting of Douglas fir and hemlock. It averaged about 32 inches in diameter, breast high. The chance from the

standpoint of down timber, brush, and dead snags was unusually difficult. There were no heavy fills.

GRADING THE RIGHT OF WAY.

Fills and cuts are introduced to equalize the irregularities of the soil, the process being known as grading.

Fills on standard gauge logging roads should be from 12 to 14 feet wide on top. The standard slopes for an earthwork fill are $1\frac{1}{2}$ horizontal to 1 vertical. When the fill is made of the material from a rock cut, it is possible to make a stable embankment with a slope ratio of 1:1. On sidehill work, where a slope of $1\frac{1}{2}$:1 or 1:1 might be a very long slope, it is often advisable to make a wall of rock or timber that will have a slope ratio of $\frac{3}{4}$:1 or steeper.

In cuts the roadbed should be wide enough to give room for a drainage ditch on either side. This will require from 2 to 3 additional feet on each side, and the cut should be about 16 feet at the base. With cuts in the hardest rock the slopes will be $\frac{1}{4}$:1, or nearly perpendicular. As the soil becomes less firm the slope may be flattened until, for a soil of firm earth or gravel, a slope of 1:1 may be permissible, although a slope of $1\frac{1}{2}$:1 is commonly adopted. The aim is to move as little dirt as possible.

Main-line logging roads are graded up carefully, and suitable ditches are maintained. Even on level sections it is desirable to elevate the track and put in ditches because of the lower cost of maintenance during wet weather. On spurs a minimum of fill and cutwork is done, and ditching is not resorted to unless absolutely necessary.

For the purpose of constructing a road as well as for calculating the earthwork, a grade profile or profiles may be prepared. This enables the engineer to fit the line to the ground in such a manner as to secure the best adjustment of the alignment and grade consistent with an economical cost of construction. It is not practical or necessary, however, for a timber appraiser to secure such intensive data, and his estimate of the cost of grading in a given case is not more than substantially correct. The appraiser's estimate, however, should be high enough to cover all cost, a liberal allowance being made to cover unforeseen contingencies that may develop during construction. Handbooks prepared for the use of civil engineers deal with the methods of calculating the cubical contents of earthwork.

The cost of the movement of earth depends to a great extent on the character of the material. The following extract from "Logging," by Bryant, shows the effect of the character of the material moved on the cost of grading:

The movement of earth and rock in the construction of cuts and fills is most frequently done by contract. The unit on which payment is based is the cubic

yard, the material being measured "in place"—that is, in the natural bank before it has been disturbed. It is customary to classify the material to be moved, and to regulate the price accordingly. The classification and quantity of material moved are determined by the supervising engineer.

The following standard classification is in extensive use:

(a) Earth, loam, sand, gravel, or clay. Material that can be handled with a pick and shovel, or that can be plowed easily.

(b) Hardpan. Very dense clays and gravels, cemented with iron oxide. Soft shales that are easily worked may also be included.

(c) Loose rock. Shales and other rock that can be quarried without blasting, although blasting may be resorted to occasionally.

(d) Solid rock. Material requiring blasting for removal.

The contract price per cubic yard for the removal of earth or rock usually includes excavating, hauling, and placing the material in a fill or waste pit. It is not customary to pay for making a cut and also to pay for a fill made from the same material; in other words, payment for a cubic yard is made but once. Grading contracts may have an overhaul clause which provides that for all earth hauled more than a specified distance ("free haul") the contractor shall be paid a stated sum per cubic yard for each 100 feet of overhaul. On logging operations the length of free haul ranges from 100 to 500 feet.

The price paid for moving material varies greatly in different regions and is influenced by the length of haul, the kind of material moved, the character of classification, the degree of accuracy used in actual classification, and the season of the year; the cost of winter work being about 25 per cent higher than that of work done during the summer.

The following prices were paid on logging railroad operations and represent general contract prices on work of this character. The average work on logging roads, except on the Pacific coast, usually presents no special problems, and can be performed with simple equipment which does not require a heavy financial outlay. Loggers are able, therefore, to contract with local men on favorable terms.

Material.	Alabama.			Louisiana.	Texas and Arkansas.	Washington.		
	Contract price.	Free haul.	Bonus for overhaul per 100 feet.	Contract price. ¹	Contract price. ¹	Contract price. ¹	Free haul.	Bonus for overhaul per 100 feet.
	<i>Cents.</i>	<i>Feet.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Cents.</i>	<i>Feet.</i>	<i>Cents.</i>
Earth.....	25	300	0.5	14	20	16-20	100	0.5
Hardpan.....			.5			25	100	.5
Loose rock.....	35	300	.5			35-45	100	.5
Solid rock.....	65	300	.5			75-125	100	.5

¹ No limit to free haul, but it was not great in any case.

Much of the grading for logging railroads is done by hand; that is, by pick and shovel work. This is particularly true of sidehill work where the bank may be picked away and shoveled to the lower side. Light work on fairly level ground is done in the same way, the dirt being borrowed from ditches or borrow pits. Frequently, moderate-sized cuts and fills, under favorable soil conditions, are handled in

the same way, the material from the cuts being mostly wasted and that needed for the fills borrowed.

Pick and shovel work is usually done by day labor, as are all other parts of railroad construction, contract work not being regarded favorably by most operators in the region. The cost of digging and spreading dirt by pick and shovel is commonly about \$0.15 to \$0.25 per yard for common loam and \$0.30 to \$0.35 for heavy soils.

In large cuts the dirt is moved to adjacent fills with wheelbarrows, two-wheeled hand dump carts, or push cars. The cost of such work, where rock is not encountered, ranges from \$0.30 to \$0.50 per yard. In very large cuts it is sometimes the practice to lay a temporary track and remove the dirt by shoveling it by hand on flat cars, the cars being hauled out on the line to a point where the dirt can be used as ballast.

Many operators supplement the pick and shovel with power scraper work. The labor cost of this work ranges from \$0.10 to \$0.25 per yard, depending on the length of haul and the class of material moved. The cost of moving dirt at one camp with a power scraper during one season ranged from \$0.28 to \$0.38 per yard. The equipment consisted of a logging engine, Bagley scraper, lines, etc., the crew and the wages per day being approximately as follows:

Engineer	\$3. 40
Fireman	3. 00
2 wood bucks, each	2. 75
Hook tender	4. 25
1 or 2 riggers, each	3. 25

The following record shows what is included in the cost of power scraper grading at this camp, also the method of keeping track of the cost:

Power scraper record.

Time.	Items of cost.	Total cost.	Cost per yard.
<i>Hours.</i>			
60.....	Moving machinery to place	\$37. 50	\$0. 0095
	Chunking right of way	262. 50	. 0668
85.....	Laying water line	40. 50	. 0103
235.....	Rent on machinery, at \$1.50	352. 50	. 0897
235.....	Engineer, at \$0.315; fireman, at \$0.275; wood buck, at \$0.25	206. 39	. 0525
235.....	Hook tender, at \$0.50	117. 50	. 0296
	Rigging men	153. 43	. 0390
	Laborers (finishing work)	69. 33	. 0176
	Yarding wood logs	16. 55	. 0042
	Total cost moving 3,927 yards	1,256. 20	. 3192

Average amount of dirt moved per hour of actual scraping time, 16.7 yards.

Ground, average conditions.

Alignment, 40° curve.

Remarks: Because of the alignment this cut was scraped from each end.

The equipment used with a power scraper consists of a logging engine, lines, blocks, etc. The cost and maintenance of the equipment, also the depreciation that should be written off annually, are discussed under "Ground yarding." In a general way this work is harder on equipment than ordinary yarding, since the percentage of time that the equipment is actually in use is larger. Several scrapers are used, the size and cost in March, 1916, of one of the best being as follows:

Size.	Cost.
4 yards -----	\$400
5 yards -----	450
6 yards -----	500

Comparatively few of the operators use a steam shovel. A $1\frac{1}{2}$ -yard dipper steam shovel suitable for heavy work costs about \$8,000 at Portland or Seattle. A smaller one with a $\frac{7}{8}$ -yard shovel costs about \$5,600 at these points.

It has not been deemed advisable or practicable to enter into a lengthy discussion of the methods and cost of grading. Information of this kind is difficult to secure. It is easy to find out the amount of money expended by a logging operator for labor in railroad construction, but it is usually impossible to get it classified into the cost of clearing right of way, grading, etc., in connection with the total length of line built, the total amount of earth moved, a classification of material moved, etc.

The cost of grading, obviously, varies greatly. In places, for short stretches, it can be done for as little as \$10 per station (100 feet). In other places it costs \$20, \$30, \$40, \$60, or more per station. Taking it straight through the country the cost of grading the spur railroads probably ranges between \$30 and \$50 per station. For example, the cost of grading 13,350 feet in one case, with pick and shovel, amounted to \$6,664, which is at the rate of about \$2,630 per mile. This does not include the cost of clearing the right of way, which was cleared for \$997 per mile. It was a scratch grade for the most part, there being no heavy cuts or fills. The average cost of clearing right of way and grading 25 miles of track in another case during 1910, 1911, and 1912 was \$2,300 per mile. The cost per station ranged between \$28 and \$64, the average being \$44. These figures do not include the cost of trestle construction. During this time, seven miles of rather heavy sidehill grade was constructed. There was little rock, and no heavy cuts or fills. The work was done by contract, the operator paying \$40 per station when the cuts and fills did not exceed 3 feet in depth. It was all done by the pick-and-shovel method. Another operator working in moderately rough ground has cleared and graded the right of way for spur tracks for

a number of years at the rate of \$1,500 per mile. Still another operator who constructs from 14 to 30 miles of spur track per year has found that the cost of clearing right of way and grading is from \$27 to \$30 per station. This work includes cuts to a depth of 10 feet, fills to a height of 7 feet, with many of the cuts and fills running more than 5 feet. The operator lets the contract to two men, and the net profit to each has never been less than \$250 per mile.

TIMBERWORK.

Much printed matter dealing with the character and cost of cribbing, trestles, revetments, etc., and methods of construction is available. A simple treatment is given in "Logging," by R. C. Bryant. For this reason the discussion given here is only very general.

(1) *Cribwork*.—In the past cribwork was extensively used and is still used in places to cross slight depressions or swampy ground. It consists of large logs laid at right angles to the track about 12 feet apart, center to center. Two logs are laid lengthwise on these logs for stringers. The cost of cribbing, when the height runs from 4 to 5 feet, is from \$0.50 to \$0.75 per linear foot, exclusive of the stumpage. From 400,000 to 500,000 feet board measure of logs is required per mile.

Cribwork, however, frequently costs more than this, as is shown in the following cases:

Case 1.—The cost of a three-stringer crib bridge 83 feet in length and 5 feet high was \$223.75, or \$2.70 per linear foot, segregated as follows:

Excavating, labor.....	\$12. 50
Construction, labor.....	116. 25
Rent of equipment.....	90. 00
Finishing, labor.....	5. 00
Total.....	223. 75

Case 2.—The cost of a cribbing 100 feet in length and averaging 10 feet in height was \$542.38, or \$5.43 per linear foot, segregated as follows:

Excavating, labor.....	\$66. 75
Construction, labor.....	290. 63
Rent of equipment.....	172. 00
Finishing, labor.....	13. 00
Total.....	542. 38

This structure forms the tail of a switchback, with two bridges resting on one foundation, the alignment necessitating three stringers. There is one span 50 feet in length and two spans 25 feet in length.

Case 3.—One camp in 1913 used crib bridges exclusively, the cost ranging from \$2 to \$6 per linear foot, exclusive of the stumpage, and varying for the most part with the height. Cribbings 20 feet in height cost about \$6 per linear foot.

(2) *Trestles.*—Trestles are used in crossing streams and depressions when the cost of fills would be excessive, also on swampy or moving ground where no other method would be practical. The advantage of this form of road on swampy ground is that a firm foundation is secured, stamps need not be removed, and the cost of maintenance for the first few years is low. The main disadvantage is the fire danger. This, however, can be minimized by clearing away the brush on each side.

Two types of trestle are used in the construction of logging railroads in the region; namely, pile-bent and frame-bent trestles.

(a) *Pile-bent trestles* are used largely in stream beds and swampy spots where good foundations for frame trestles can not be secured. They are used extensively, however, in locations adapted for the frame-bent type. Low pile trestle bents, up to a height of 25 feet, consist of 3 or 4 piles from 12 to 15 inches in diameter. On medium height trestles, from 25 to 60 feet, four piles are used. They are driven in a row across the roadbed with a pile driver to bedrock or solid bottom, being sawed off at the required height above ground. Hewn caps, 14 feet long, 12 inches and up in thickness, with not less than a 12-inch face, are drift-bolted on top of them. The bents, which are spaced 16 feet apart, are connected by two hewn or sawed stringers 16 or 32 feet in length and 17 inches and up in thickness, with 12 to 16 inch faces, a stringer being placed under each rail on top of the caps and at right angles to them to support the crossties. In many cases hewn stringers prove the cheapest in the long run.

Guard rails are placed on top of the ends of the ties parallel to the stringers and spiked to every other tie to keep the ties from bunching. Trestles over 25 feet in height, as a rule, are braced by standard methods. If a trestle curves heavily it is braced, even though it is no more than 15 feet high.

The labor cost of constructing pile-bent trestles of the above description is about as follows:

Average height :	Cost per linear foot. ¹
5 to 10 feet (no bracing) -----	\$2.00
10 to 15 feet (no bracing) -----	2.20
15 to 20 feet (no bracing) -----	2.50
20 to 25 feet (with bracing) -----	3.00
25 to 40 feet (with bracing) -----	4.00
40 to 60 feet (with bracing) -----	5.00

¹ Includes the cost of yarding the material to the site.

The following is the cost of several pile-bent trestles built in logging camps of the region during the past few years:

Case 1.—The labor cost of a pile-bent trestle 1,800 feet long and averaging 5 feet in height amounted to \$900, or \$0.50 per linear foot. The bents consisted of three piles; the caps and stringers were hewn hemlock timber.

Case 2.—The cost of building a three-pile-bent trestle 160 feet in length and averaging about 20 feet in height amounted to \$464, or \$2.90 per linear foot, the cost being made up as follows:

Excavating.....	\$106
Labor, including surveying to the amount of \$40.75.....	265
Rent of machinery.....	60
Finishing (including laying of steel).....	33
Total	464

This amount includes the cost of yarding the material to the site. It does not include the cost of timber or iron used. The caps and stringers were made of hewn timbers.

Case 3.—The cost of building a pile-bent trestle 1,200 feet in length and averaging about 10 feet in height amounted to \$5,428.31, or \$4.52 per linear foot, the cost being made up as follows:

Stringers, caps, and iron.....	\$1,450.81
490 piles (25 feet in length) at 7 cents per foot.....	857.50
Towing piling.....	70.00
Lumber, 14,000 feet, at \$8 per thousand.....	112.00
Labor.....	2,938.00
Total.....	5,428.31

Case 4.—The cost of a pile-bent trestle 135 feet in length and averaging about 28 feet in height was \$5.20 per linear foot. This includes the cost of yarding the material to the site and building the trestle, also a rental of \$5 per day on the equipment. It does not include the value of the timber, sawed or otherwise.

The bents consisted of four piles, the trestle being 47 feet at the highest point. Hemlock piling, hewn hemlock caps, and sawed bracings were used. There were three sets of bracing, made of 3 by 8 inch and 3 by 10 inch material.

Case 5.—The cost of building a pile-bent trestle 160 feet in length and averaging about 20 feet in height was \$2.50 per linear foot. This includes the cost of yarding the material to the site and building the trestle, also a rental of \$5 per day on the equipment. The bents consist of three piles, the highest point on the trestle from the ground being 20 feet. Rough hemlock timber was used for piling, caps, and stringers.

Case 6.—The cost of a pile-bent trestle 160 feet in length and having an average height of 8 feet was \$2.40 per linear foot. This

includes the cost of yarding the material to the track and building the trestle, and also a rental of \$5 per day on the equipment. The bents consisted of three piles, the highest point on the trestle from the ground being 12 feet. Rough hemlock timber was used for piling, caps, and stringers.

Case 7.—The cost of building the following pile-bent trestle was \$389.05, or \$2.28 per linear foot. This total does not include the value of the timber used for piling, nor the value of the sawed caps, stringers, and bracing.

Structure.

Total length	feet.....	170
Number of piles		39
Average length of piling	feet.....	20
Average penetration of piling	feet.....	10
Sawed caps		7
Sawed stringers, 8 by 16 inch Douglas fir.		
Bracing, 300 feet b. m. (3 by 12 inch).		
Alignment: 100 feet, 28°; 70 feet tangent.		

Cost.

Moving machinery to place	\$42.77
Yarding material to site	33.75
Driving piling	117.36
Placing stringers and caps	77.46
Laying track	18.50
Excavating	17.12
Surveying	19.09
Drift bolts, 200 pounds, at \$2.25 per 100 pounds	4.50
Rent of equipment	58.50
Total	389.05

The cost of driving piling for pile-bent-trestle construction varies. In one case piling was driven, cut off, and capped at the rate of \$1.86 per pile.

The daily cost was as follows:

Foreman	\$4.00
Engineer	3.50
Fireman	2.75
3 men, at \$3	9.00
Total labor cost	19.25
Rental on equipment	10.00
Total cost	29.25

Average daily output, 16 piles driven and capped.

This trestle was 2,000 feet long and consisted of three-pile bents, spaced 16 feet apart. It averaged about 10 feet in height, the penetration of the piling averaging about 15 feet.

(b) Frame-bent trestles are made of both round and sawed timbers. If the former material has to be brought from a considerable distance, it is advisable to use the latter, since it is easier to fit and is more durable. On the longer main-line logging roads, most of the frame trestles are built of sawed timber, the trestles on the spurs being usually built of round timbers. Not infrequently, however, the stringers used in connection with the construction of the trestles on these latter roads consist of sawed timber. Where suitable pole timber is available, a rough-timber trestle can be constructed more cheaply than one with a sawed frame.

The general appearance of a frame trestle is much the same as that of a pile trestle. The bents, which are spaced 13 to 16 feet apart, consist of four legs made of round timbers 14 inches and up in diameter or 10 by 10 inch or larger square timbers. Each bent rests upon a sill, which may be either a log or a 10 by 12 inch sawed timber. Round or sawed timbers are used for caps and stringers.

In computing the cost of frame trestles, the lumber used is commonly included at \$12 per thousand feet. A convenient way of figuring the cost of any trestle is at so much per 1,000 feet of the material contained in it. This cost includes lumber, bolts, and other supplies, and the labor of building the foundations and framing the trestle. The cost of several representative standard-gauge frame trestles recently constructed on logging railroads in this region is given in Table 31.

TABLE 31.—*Cost of frame trestles.*

Length, feet.	Maximum height, feet.	Feet b. m.	Total cost.	Cost per M feet.	Cost per linear feet.
620	52	105,000	\$2,800	\$26.66	\$4.52
652	28	60,000	1,565	26.08	2.40
762	8	68,000	1,704	25.06	2.23
202	32	28,000	743	26.54	3.68
140	34	19,000	487	25.63	3.34
238	31	31,000	724	23.35	3.04
272	41	45,000	1,030	22.89	3.77
144	54	30,000	713	23.76	4.95

TRACK MATERIALS.

The following discussion has to do with standard-gauge material.

Crossties.—Both sawed and hewn ties are used in constructing logging railroads. Where the logging operator is also engaged in the manufacture of lumber, and the sawmill is close to the logging camp, most of the ties used are sawed. Independent loggers, as a rule, use hewn ties exclusively.

Sawed ties vary in size. The usual size on standard-gauge roads in the region is 7 by 9 inches by 8 feet. Ties 7 by 8 inches by 8 feet

are also used. In many cases ties 6 by 8 inches by 8 feet are used on side tracks. A large percentage of the sawed ties used in logging roads are culls.

Common-carrier roads, in purchasing hewn ties in the region, generally demand that the ties shall be made of Douglas fir and be peeled; that they shall not be less than 8 feet nor more than 8 feet 2 inches long, with the ends sawed off square; that they shall be hewn on two sides, straight and true to an even thickness of 7 inches; that they shall not be less than 6 inches, nor more than 9 inches, wide at the widest place on the face; that there shall not be less than 56 square inches at the smallest cross section; and that ties shall be made from sound, live timber, "taken out of wind," and free from splits, shakes, unsound knots, and score hacks. They will, however, accept 10 per cent of No. 2 ties, which are similar in every respect to No. 1 except that they may range from 7 feet 11 inches to 8 feet 3 inches in length and may be 50 square inches at the smallest cross section.

The specifications of hewn logging railroad crossties, here designated as No. 3 ties, sometimes provide that ties shall not be less than 7 feet 9 inches nor more than 8 feet 3 inches in length; that they shall not be less than $6\frac{1}{2}$ inches in thickness; and that the width of the face at the smallest end shall not be less than $6\frac{1}{2}$ inches.

In one case, a logging operator paid a contractor \$0.23 per tie for making and delivering No. 1 hewn ties along the right of way, the contract providing that 10 per cent of the ties could be No. 2's. The contractor was paid \$0.19 for making and delivering No. 3's along the right of way. The tie contractor sublet the contract, paying \$0.11 for No. 1 and No. 2 barked ties in the string. Where the ties were hewn, barked, and sawed, the tie contractor paid \$0.13 per tie. The tie makers received \$0.085 for No. 3 hewn ties in the string. The ties had to be skidded an average distance of from 150 to 200 feet to the right of way. The contractors, as a rule, received about \$0.16 per unbarked logging-railroad tie; that is, for making the ties and delivering them along the railroads. Ties used in the construction of logging railroads in the region are, as a rule, made of Douglas fir and hemlock, preferably the former. The above cost does not include the value of the stumpage.

The number of ties used per mile depends on the character of the roadbed, the size of the rail, the weight of the locomotives used, character of the ties used, etc. In the more or less permanent main logging railroads, 16 ties per 30-foot rail, or 2,816 ties per mile, are ordinarily used. Where the ties are small and inferior, 17 or 18 may be used per 30-foot rail. This latter is particularly applicable to the spur lines. Sometimes 14 or 15 are used per 30-foot rail.

The volume of timber in sawed ties when 2,992, 7 by 8 inches by 8 feet ties are laid per mile amounts to 111,600 feet, and 95,700 feet when the same number of 6 by 8 inches by 8 feet ties are laid. At \$12 per thousand feet, the cost per mile for ties is \$1,339.20 in the first instance, \$1,148.40 in the second. The cost of hewn ties per mile ranges from \$600 to \$750.

Ties used in main-line logging railroads last seven or eight years, provided a good class of Douglas fir ties is used. Six years is a conservative figure. Ties used in spur roads do not last so long, since the operation of taking them up and relaying them is hard on them. Spur railroad ties may be used in three or four different locations, provided the total period of use does not exceed four or five years.

Steel rails.—Rails are classified according to their weight in pounds per linear yard. They are sold by the long ton. While the standard rail length is 30 feet, shippers reserve the right to include 10 per cent of from 24 to 28 foot rails in a given order.

Rails varying from 45 to 60 pounds per yard may be observed on the logging railroads in the region. Fifty-six and 60 pound rails are the more common, 60-pound on the main lines, 56-pound on the spurs. Many operators, however, use 60-pound steel on both the main line and spurs.

The use of heavy rails has paid. They depreciate less in use and in the lifting and relaying. Furthermore, they can be used with fewer ties and on a poorer roadbed than the lighter rails.

The number of long tons of rails of different weights required per mile may be found by multiplying the weight per yard by 11 and dividing the result by 7.

Example: Weight of rail, 60 pounds per yard, then $\frac{60 \times 11}{7} = 94$ tons and 640 pounds.

The weight in tons of several representative sizes of rails per mile is as follows:

Weight of rail per yard.	Weight of track per mile.	
<i>Pounds.</i>	<i>Tons.</i>	<i>Pounds.</i>
45	+70	1,600
50	78	1,280
56	88	-----
60	94	640
65	102	320
70	110	-----

The following were the f. o. b. prices of steel rails in Chicago in March, 1914:

45 pounds per yard and down, \$27 per ton.
50 pounds per yard and up, \$28 per ton.

The freight rate from Chicago to Pacific coast terminal points is \$11 per ton. In estimating the cost of the rails to be used in a given case, one should add the cost of transporting the rails from the terminal point to the camp.

In 1914, first-class relaying rails at Pacific coast terminal points were worth about as follows:

45 pounds per yard and down, \$35 per ton.

50 pounds per yard and up, \$36 per ton.

Second-class inspected relaying rails were worth about as follows:

45 pounds per yard and down, \$29 per ton.

50 pounds per yard and up, \$30 per ton.

It is customary to figure the life of steel rails at 20 years. This is, no doubt, about right for the rails used in main-line logging roads. Possibly it is too high for rails used on spurs, where the grades and curvature are heavy, the roadbed is relatively poorer, and the steel is taken up and relaid often. A life of 15 years, with a scrap value of 20 per cent of the initial cost, is thought to be a better basis for estimating the depreciation on rails so used.

Angle bars.—Either angle bars or fishplates are used to strengthen and brace the rails at the joint. The usual method is by means of angle bars. They are bolted on each side of the joint with two bolts in each rail head.

The weights of angle bars for four typical weights of rails are as follows:

Size of rail.	Weight of angle bars per pair.	Weight of angle bars per mile. ¹
	<i>Pounds.</i>	<i>Pounds.</i>
45-pound rail.....	21.5	7,675
50-pound rail.....	23.4	8,354
56-pound rail.....	28.0	10,396
60-pound rail.....	31.4	11,210

¹ Standard requirements call for 352 joints per mile.

The cost of angle bars f. o. b. Pacific coast terminal points in 1916 was approximately \$2.05 per hundredweight. The cost of angle bars per mile for four typical rails is as follows:

Size of rail.	Cost of angle bars per mile of track. ¹
45-pound rail.....	\$158.00
50-pound rail.....	172.00
56-pound rail.....	213.00
60-pound rail.....	230.00

¹ Amounts do not include the cost of transportation from Pacific coast terminal points to the right of way.

Bolts and nuts.—Four bolts and nuts are required at each rail joint. They come in kegs of 200 pounds each. The approximate price at Pacific coast terminal points is \$3 per hundredweight, or \$6 per keg. With hexagonal nuts, the quantity required per mile, also the cost, is as follows:

Rail.	Size of bolts.	Number in keg.	Number of kegs per mile.	Cost per mile.
	<i>Inches.</i>			
45-pound rail.....	3 by $\frac{3}{4}$	245	5.2	\$31.00
50-pound rail.....	3 $\frac{1}{2}$ by $\frac{3}{4}$	270	5.7	34.00
56-pound rail.....	3 $\frac{1}{2}$ by $\frac{3}{4}$	270	5.7	34.00
60-pound rail.....	3 $\frac{1}{2}$ by $\frac{3}{4}$	270	5.7	34.00

Spikes.—Rails are fastened to the crossties by square spikes, which are usually $5\frac{1}{2}$ inches by $\frac{3}{16}$ inch under the head. Four spikes are driven to each tie, one on each side of the rails. The cost f. o. b. Pacific coast terminal points is approximately \$2.50 per hundredweight, or \$5 per keg. There are 400 of these spikes in a keg, and about 29 kegs are required per mile. The cost of spikes per mile of track is about \$145.

Turnouts.—A turnout is a contrivance for passing from one track to another. The principal parts are the switch, the frog, and two guard rails. There are two kinds of switches, stub and split. The split switch is generally used on the logging roads because of its greater safety. A turnout for 60-pound rail, including switch, frog, guard rails, ground throw and rail braces, costs about \$100. With a high stand it costs about \$10 more.

STEEL LAYING AND REMOVAL.

Laying and removing the rails, as a rule, is done by hand. It is done both by contract and day labor, the latter being by far the more common practice. For several reasons it is not known just what it costs logging operators to lay and lift track. Very few operators keep their accounts in such a way as to make this information available. Then, too, this cost does not always include the same items of expense. Furthermore, conditions, wages, and efficiency of labor, etc., vary. Those desiring to secure a knowledge of cost of this work should familiarize themselves with what is said in connection with common carrier roads, bearing in mind that logging operators generally pay higher wages, secure less efficient help, and seldom work under as favorable conditions.

Track laying is here considered as the operation of loading the ties, rails, etc., on the cars, unloading this equipment, placing the ties and rails, and curving and jointing the rails. The cost of train service is not included unless it is so specified.

To lay the track costs from \$250 to \$325 per mile. One superintendent who has directed the building of more than 25 miles of logging railroad during the last three or four years estimates the cost of laying 1,000 feet of standard-gauge track with new steel as follows:

Rental on locomotive.....	\$10
Train crew, fireman, and engineer.....	7
Foreman	4
Twelve hands, at \$2.50.....	30
Total	51

This is at the rate of about \$270 per mile.

As logging progresses, the track is lifted and relaid on new spurs. This work usually takes place at the same time. Ordinarily, track can be lifted and laid for from \$10 to \$12 per station, the cost of lifting by hand when both rails and ties are taken up being about the same as the laying of the track.

The cost of installing switches, when labor is paid at the rate of \$2.50 per day, amounts to about \$20 per switch.

The cost of surfacing, which consists of shoveling earth in between the ties, aligning the track, and tamping, amounts to about \$300 per mile.

Quite often material suitable for filling between and under the ties is not at hand and has to be hauled in on cars. Foreign material, usually consisting of gravel or broken rock, is known as ballast. Whether some material other than that found along the right of way is used will depend on the formation of the roadbed, the material along the right of way, what seasons of the year the track is to be used, and the period of time the track is to be used. If a spur is going to be used only during the dry season, no rock ballast will be used. Then, too, if rock ballast is very scarce, it will not be used on spurs during other seasons of the year. The same factors apply to the amount of ballast that should be used in a given case.

In estimating the cost of surfacing with ballast one should know the character of the ground through which the right of way runs, also where ballast can be found. Where ballast is scarce and has to be hauled in at some distance the cost per mile may be considerable. The cost of surfacing the main-line logging railroad in one case amounted to \$1,800 per mile; in another case, \$1,200 per mile. Most operators have found that it pays to use plenty of rock, gravel, or other ballast on lines that are to be in use some time, since by so doing they reduce the cost of maintenance by more than enough to offset the cost of ballasting. Other advantages also result from a well-ballasted track.

TOTAL COST OF BUILDING LOGGING RAILROADS.

The total cost of building $4\frac{3}{4}$ miles of logging railroad in one case, exclusive of ties, steel, fixtures, and certain other items indicated in the following discussion of the cost, was as follows:

Items.	Total cost.	Cost per mile.
Engineering and superintendence.....	\$2,012.25	\$423.63
Construction, buildings, etc.....	60.00	12.63
Grading tools.....	102.76	21.63
Clearing right of way.....	2,295.00	453.16
Labor grading.....	8,824.05	1,857.70
Powder grading.....	1,247.57	262.65
Stringer bridges.....	565.50	119.05
Trestles on hill.....	4,623.63	973.40
Trestles at slough.....	4,132.00	869.89
Labor laying track.....	2,821.50	594.00
Labor surfacing.....	6,223.65	1,310.24
Total.....	32,907.92	6,927.98

Starting at the bottom of the hill, the first 975 feet consisted of a pile-bent trestle. Another pile-bent trestle, 2,325 feet long, branching from the main line and running in the same general direction, is included in the above cost. From the end of the first trestle the road passed along a very steep hillside, over one switchback, and around an oxbow. From the beginning to the end of the first $2\frac{1}{2}$ miles of graded track the air-line distance was $1\frac{3}{4}$ miles. The last $1\frac{3}{4}$ miles was fairly light construction, the road traversing rolling ground which was swampy in places. The maximum curve was 30° and the heaviest grade (favorable) was $6\frac{1}{2}$ per cent. After the top of the hill was passed there was an adverse grade of 5 per cent. The grade from the bottom to the top of the hill averaged 4 per cent.

The cost of the engineering and superintendence includes the cost of the location and supervision, the salary and expenses of the resident engineer, also the salaries of his assistants.

The preliminary work includes the cost of constructing living quarters for the laborers and pile-driving crew, also an office. Twenty-five per cent of this cost was charged against the railroad construction work. The cost of structures was as follows:

Material.....	\$127.30
Labor.....	112.65
Total.....	239.95

The total cost of grading tools was \$308.29. These tools at the completion of the work were transferred to the logging department, $33\frac{1}{3}$ per cent of their cost, or \$102.76, being charged against the grading. Practically all of the grading was done by hand.

The cost of wire rope used in yarding material along the right of way and in driving piling, blocks, hooks, peavies, pike poles, logging-

engine repairs, oil, waste, grease, packing, etc., amounted to \$975.17. At the completion of the road all this equipment, with the exception of lines and blocks, was transferred to the logging department, the construction department being credited with \$100, leaving \$875 charged against the construction work. The latter amount was written off as follows: \$488 against the "hill trestles"; \$427 against the "slough trestles."

The work of clearing the right of way includes the felling and bucking and swamping on the 30-foot right of way. The right of way ran through a fairly heavy stand of second-growth Douglas fir. On the hillside, about one-half the total distance, it was entirely handwork, the timber being felled clear of the right of way. The down timber on this part of the road was cut in short lengths and handled with peavies. On other parts of the lines, a logging engine was used in removing timber from the right of way. Large charges of powder were used. The cost of clearing at the trestles was not charged against the right of way, but against the trestle-constructing crews.

The cost of this work was segregated as follows:

Labor	\$2, 035. 35
Powder	259. 65
Total	2, 295. 00

The hand work cost about \$528 per mile; the machine work about \$419. The powder delivered cost about \$0.105 per pound.

The following wages per day were paid:

Hand clearing.

Foreman	\$3. 50
Powder man	3. 00
Laborers	2. 00
Head fallers	3. 75
Second fallers	3. 40
Buckers	3. 25

Machine work.

Foreman	\$5. 00
Engineer	3. 40
Rigging men	3. 00 to 3. 25
Fireman	2. 75

The grading work was done entirely by hand. Eliminating the bridge and trestle work, there were 3 miles and 2,834 feet of line graded; 39,402 cubic yards of earth were moved on the entire line, being at the average rate of 211 cubic yards per station. The material was classified as follows: 90 per cent of earth; 8 per cent of loose rock (a soft sand rock); 2 per cent of solid rock.

The total cost of grading was classified as follows:

Labor	\$8,824.05
Powder	1,247.57
Total (3.53 miles)	10,071.62

The average cost per mile when based on 3.53 miles of actual grading was \$2,853.00; when based on 4.75 miles, or the total length of the line, \$2,120.34. The following wages were paid: Grading foreman, per day, \$3.50 to \$4; laborers, per day, \$2.

There were 1,450 feet of cribbing for stringer bridges built on ground that was soft during parts of the year. The conditions were ideal for this kind of work, since the timber was long, straight, second-growth fir. The mud sills were spaced about 20 feet apart. The stringers were not barked, neither were they hewn on top.

The hill trestles, 15 in number, were frame-bent structures. In length they ranged from 48 to 224 feet; in height from 10 to 45 feet, averaging about 20 feet. Their total length was 1,656 feet. The bents were spaced 16 feet apart center to center. Hewn caps and stringers were used. The caps were 12 feet long and hewn to a 12-inch face on two sides; the stringers, 15 inches thick and hewn to an 8-inch face on two sides. The value of the stumpage included in these structures, as well as in other bridges, is not included in the cost. As these trestles were constructed on a steep side-hill, their cost was higher than it would have been on level ground. The cost was segregated as follows:

Items.	Total cost.	Cost per linear foot.
Labor	\$3,567.10	\$2.15
Bracing, material	378.56	.228
Spikes and drift bolts	229.80	.132
Bridge tools	448.17	.270
Total	4,623.63	2.78

The cost of the trestle at the slough does not include laying the ties and steel. The following items were segregated:

Items.	Total cost.	Cost per linear foot.
Labor	\$2,187.00	\$0.63
Bracing, material	70.00	.021
Drift bolts	122.00	.037
Piling, caps, and stringers	1,242.00	.373
Brow skid straps	84.00	.025
Tools	427.00	.127
Total	4,132.00	1.213

The above includes the cost of building 3,300 feet of 3-pile bent trestle, together with a 300-foot log dump, the driving of the piling,

hewing and placing the caps and stringers, and the cost of the material. The trestles averaged about 8 feet in height, the bents being spaced 15 feet apart. The penetration of the piles was about 15 feet. Five thousand feet of lumber were used in the bracings, which cost \$14 per thousand feet; 41,400 feet of piling, caps, and stringers were used, which cost \$0.03 per linear foot delivered along the right of way.

The cost of labor for laying track was high, because 85 per cent of the line consisted of heavy curves with short tangents between. Fifty-six-pound steel was used. About 3,000 ties were laid to the mile. All bridges were double guard-railed; all curves single guard-railed. The foreman was paid \$3.50 per day; the laborers, \$2 per day.

The track was surfaced with from 12 to 15 inches of broken-rock ballast. This was blasted out of a pit, broken, and loaded by hand, so that it was very expensive.

MAINTENANCE OF WAY.

Section screws are employed to keep the road ballasted up, maintain the gauge, keep the ditches open, replace broken or decayed ties, and to make any other repairs that are necessary. The cost of this work per thousand feet depends on several factors. The following are the most important:

(a) The cost per 1,000 feet is higher the greater the length of line in use.

(b) The volume of timber hauled per year is a factor which operators can very easily overlook at the start, and which market conditions may make it difficult to control during the life of the operation. Ordinarily operators arrange for sufficient timber to enable them to write off the cost of railroad construction economically. The supply of timber does not, however, automatically take care of the maintenance of way, since this cost is distinct from railroad construction. While an exceedingly heavy traffic possibly requires more of an expenditure to keep a railroad in condition, there is no question that a small volume of traffic requires more proportionately. Because of this, the tendency is to increase the annual cut as the length of haul increases. Moreover, the recognition of this fact by the industry is one of the reasons why operators continue to run after market conditions suggest that they should close down.

(c) The maintenance cost in some cases is unnecessarily high because the road was poorly constructed in the beginning, the result being that the construction of the road really continues throughout the life of the operation. The tendency at the present time is to build better logging railroads.

(d) The principal part of the maintenance of way is the labor of section crews. Ordinarily five men under a section foreman should keep 6 miles of main line logging railroad in good condition.

With the exception of a small expenditure for tools and rail fastenings, the rest of track maintenance is made up of tie replacements. The life of ties is taken up in the discussion headed "Track materials" in this section.

EQUIPMENT.

The equipment in the main consists of locomotives and cars or trucks.

(1) *Locomotives*.—There are two general types of locomotives used, rod or straight connected, and geared. The type used in a given case is determined largely by the grades and curvature of the road.

The rod engine is universally used on the common carrier railroad. In it the power is transmitted from the cylinders to the drivers by means of a connecting rod. Rod locomotives have a longer wheel base than geared locomotives, and so can not take as sharp curves. They make better time, however, and cost less for maintenance, proving the most satisfactory type on relatively long hauls and where the road is smooth, well maintained, and of easy grade. To secure good service with a rod engine, the maximum grade empty should not exceed 3 per cent; the maximum grade loaded, $1\frac{1}{2}$ per cent. However, there are a number of rod engines working on roads having grades of 5 per cent. The maximum curves permissible are about 25 degrees.

A special form of rod locomotive is used to a limited extent in the region. Its essential features are two sets of engines mounted under the boiler, each connected to two independent groups of drivers. This has the effect of materially shortening the wheel base, permitting the use of heavy rod locomotives on roads having curves that are too sharp for the regular type of rod locomotive of the same weight. It is claimed that this engine can start greater loads than the ordinary rod engine of the same weight. One weighing 121 tons is operated on a road having 35-degree curves and 8 per cent grades. There are several makes of rod locomotives on the market.

Bryant, in "Logging," states that the first geared locomotive was constructed about 1885 by E. E. Shay, a Michigan logger; and this type of locomotive, with some modifications and improvements, is in extensive use to-day. Two other forms of geared locomotives are now in use in the region.

Most of the locomotives used in logging in the region are of the geared type. This is because sharp curves, heavy grades, and relatively rough roadbed, which the geared locomotive is designed to

overcome, are characteristic of logging railroads. Geared locomotives may be observed working on main-line logging railroads where the grades are 2 per cent for loaded trains and 5 per cent for empties, and on spurs where the grades are as high as 7 or 8 per cent, or even 10 per cent on short stretches for empties and 5 per cent for loaded trains.

With the geared locomotive, every wheel under the locomotive and tender is a driving wheel, the wheels being arranged in pairs on swivel trucks. The trucks are connected one with another by an articulating shaft, the power being transmitted to the driving wheels through a series of bevel gears. This arrangement gives a maximum amount of tractive force with a minimum total weight, a short-truck base, and a form of truck that will readily adjust itself to an uneven track. There are two types of geared locomotives; namely, the center shaft and side shaft.

The weight of the locomotives used in the region varies, depending on the maximum grades and maximum loads. In the case of the rod engines, the total weight ranges from 42 tons or less to 120 tons. The larger engines are used for long hauls. The weight of the geared locomotives ranges all the way from 42 tons or less to 100 tons. Most of these locomotives, however, range from 42 to 60 tons, 42 and 50 ton locomotives being used on the spurs, 60-ton locomotives on the main lines. Locomotives of the latter weight are also used on the spurs.

The hauling ability of a locomotive depends largely on the tractive force, the frictional resistance, and the resistance of the road to gravity. The tractive force is the power for pulling a train, including its own weight, and amounts in pounds, as a rule, to from 20 to 23 per cent of the total weight on the drivers. The resistance due to friction varies with the character and condition of the roadbed and rolling stock. Logging cars of good construction and with well oiled bearings should have a rolling friction of from 12 to 20 pounds per ton of weight handled. Where the conditions are first class, this will not be too high; but if the roadbed is poor and the journals are not well oiled, the rolling friction may be as much as 25 or 30 pounds. The frictional resistance due to curves is extremely variable, since it is governed by so many factors, of which the degree of curvature is the principal one. It is the general rule to assume the resistance due to curves for standard gauge to be one-half pound per ton per degree. The grade resistance is 20 pounds per ton for each 1 per cent of grade.

The hauling capacity of a locomotive, in tons of 2,000 pounds, is determined by dividing the tractive force of the locomotive by the sum of the resistance due to gravity, rolling friction, and curve resistance, and then deducting from this result the weight of the loco-

motive and tender. The estimated hauling capacity of given weights and types can usually be found in catalogues of manufactures. In Table 32 the estimated hauling capacity of rod and geared locomotives is given.

The approximate cost in 1914 of rod and geared locomotives at Pacific coast terminal points was as follows:

TABLE 32.—*Cost, weight, and capacity of engines.*

ROD.

Weight.		Hauling capacity (exclusive of engine and tender).				Cost.
Total.	On drivers.	Level.	1 per cent.	3 per cent.	4 per cent.	
<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	
42	31	1,240	415	140	90	\$9,500
55	40	1,630	545	185	125	11,200
67	49	1,970	665	225	150	13,900
71	57					14,500

GEARED.

Weight in work- ing order.	Hauling capacity (exclusive of engine and tender). ¹								Cost with air brake.
	Grade.								
	Level.	$\frac{1}{2}$ per cent.	1 per cent.	2 per cent.	3 per cent.	4 per cent.	5 per cent.	6 per cent.	
<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	<i>Tons.</i>	
24	1,312	570	357	198	133	97	74	59	\$5,670
28	1,550	673	422	235	158	116	90	72	6,490
32	1,740	757	476	265	179	132	102	81	7,040
36	1,815	788	493	273	183	133	102	81	7,910
42	2,071	900	563	311	207	151	115	91	8,260
50	2,497	1,083	679	377	252	184	141	112	9,450
60	2,922	1,266	793	438	292	212	162	127	10,610
70	3,698	1,591	990	554	372	271	209	166	11,890
80	4,301	1,868	1,169	648	434	317	242	192	14,980
90	4,965	2,160	1,360	755	508	374	289	230	16,090

¹ Hauling capacity given is calculated on an assumed rolling friction of 8 pounds per ton.

These prices do not include oil-burning equipment, which can be installed for from \$400 to \$500 per boiler. For shipment to the Pacific coast all locomotives under 42 tons in weight are loaded on flat cars, and the freight rate is \$1.50 per hundredweight. Larger locomotives are shipped on their own trucks at a rate of \$0.88 per hundredweight, plus \$200 for a messenger to accompany the engine. For 32-ton to 80-ton locomotives the shipping weight is from 5 to 8 tons less than the working weight.

It is not possible to state the maintenance cost of locomotives, because it depends on so many factors. One logging superintendent is of the opinion that it ranges between \$600 and \$1,000 per year. He stated that the upkeep of three locomotives, 18, 36, and 42 ton, during the last year of operation amounted to \$2,425, and that the upkeep of a 60-ton engine, which averaged 60 miles per operating

day, amounted to \$1,121 during this year. Another logging superintendent estimated the maintenance cost per year of locomotives as \$600 for rod and \$1,100 for geared.

The following data, based on four years' time, were furnished by a logging superintendent. The information has to do with four geared locomotives, one 60-ton and three 50-ton.

Maintenance cost of locomotives.

Year.	Number of locomotives.	Total yearly cost.	Average cost per locomotive.	Total amount timber hauled (feet).	Average amount timber hauled per locomotive (feet).
1908.....	4	\$1,540	\$385	28,000,000	7,000,000
1909.....	4	1,620	405	27,000,000	6,750,000
1910.....	4	3,000	750	40,000,000	10,000,000
1911.....	4	1,100	275	38,000,000	9,500,000
Total.....		7,260			
Average.....		453			

If locomotives have the proper kind of treatment, the maintenance cost per year will probably range from \$400 to \$700 for geared locomotives and from \$300 to \$400 for rod locomotives.

The service demanded of locomotives on logging railroads is usually severe, the result being a relatively short life. For the purpose of a timber appraisal, the life of rod locomotives used on a main-line logging railroad may be placed at 20 years, the life of geared locomotives at 15 years. If the work to be done by the latter type is particularly trying, 12 years should be used.

Cars.—Three types of log cars are used in the region; namely, flat cars, skeleton cars, and separate trucks.

Flat cars are not used to any extent except where the logs are hauled over a common-carrier railroad, in which event the cars are not owned by the logging company. Of course, all logging companies have three or more for use in connection with construction work, etc. There are a number of makes and sizes on the market. The standard low logging flat car, built in the region, is 41 feet long and accommodates 42-foot logs. It has a capacity of 80,000 pounds, weighs 26,700 pounds, and costs about \$850 f. o. b. Seattle. When equipped with very satisfactory patent bunks and chocks it costs about \$925.

The skeleton car consists of two pair of four-wheel trucks joined together by heavy timbers, and is very satisfactory where it is desirable to use air brakes. One make, which is used as much as any, costs about \$750 f. o. b. Seattle. This price includes air equipment, also patent bunks and chocks and automatic couplers. The car is built in lengths up to 56 feet over all, has a capacity of 80,000 pounds, and weighs about 19,000 pounds.

In most cases where the logs are not hauled over common-carrier railroads, disconnected trucks are used. There are a number of makes and sizes on the market. One truck, which is used as much as any, cost about \$750 per set f. o. b. Seattle in 1913. This price includes patent bunks and chocks, also automatic couplers. Each truck is equipped with chains for binding on the logs. These chains cost about \$20 extra per set of trucks.

The number of cars required varies considerably. Where the output amounts to from 175,000 to 200,000 feet per day, the number ranges from 25 to 60 or more. The number required for a given operation depends on the following:

(1) The amount of timber handled daily. (2) The volume of the average load, which runs from 6,000 to 8,000 feet. (3) The average number of cars hauled per trip. (4) The method of loading. If it is possible to store logs on the landing without interfering with the operation of transporting the logs from the stump to the landing, a smaller number of cars may be employed than where the logs have to be loaded practically at the time they are delivered at the landing. (5) Method of unloading. The longer it takes to unload the logs, the greater the number of cars required. (6) The distance that the logs have to be hauled, also the number of divisions the road is divided into.

For the purpose of a timber appraisal, the maintenance cost of flat cars may be placed at about 10 per cent of the purchase price; skeleton and disconnected trucks, at about 6 to 8 per cent of the purchase price. The life of flats and trucks may be figured at from 10 to 12 years. If they are kept in proper repair, their life will be much longer than this.

OPERATION.

Under this heading will be discussed the cost of transporting logs from the landings to the dump. The elements of cost are the same as for yarding, loading, etc.

A general idea of the operation of logging railroads has been given. The labor required, as well as the amount of equipment, depends upon the daily output, length of haul, grades, etc. In some operations one locomotive is sufficient. This engine hauls the empties out to the woods, switches them to the landings, picks up the loaded cars, and hauls them to the dump. Larger operations with longer main lines require a locomotive in the woods distributing the empties and switching out the loaded cars to a point where they can be picked up by the main-line locomotive. Still larger operations require four or five locomotives. If the output is large and the haul long, two of them may work on the main line.

The number of locomotives and train crews employed should be ample to keep plenty of empties available at the landings, since

delays in the yarding and loading department caused by waiting for cars materially increase the cost of these steps in the operation.

The average volume of timber hauled from the landings to the dump per locomotive per day seldom amounts to less than 50,000 feet or more than 100,000. Taking it straight through the region, the average output of timber per locomotive per day amounts to about 75,000 feet. It should be borne in mind, however, that average figures of this character are of little value.

To get an estimate of the number of cars and locomotives to be used, which has a direct bearing on the items of depreciation, replacements, maintenance, supplies, and labor, the timber appraiser works roughly as follows:

The total amount of timber included in the sale, the period allowed for the removal of the timber, and the length of the cutting season fix the average amount that should be logged daily. Whether the transportation of this amount will require the services of one, two, three, four, or more locomotives is the next thing to be decided. If a proper field examination has been made, the appraiser knows the approximate lengths of the different hauls during different periods of the operation, also the approximate rise and fall on different sections of the track, which information will determine the type and weight of the locomotives to be used. The appraiser then estimates the number of locomotives or the number of train crews. In a given case he may decide that one locomotive will be ample for the first two years; that after the second year two will be required; and that after the fourth year three will be required. In this way he arrives at a basis for estimating the labor and other costs per thousand feet for operating the trains.

In connection with the above it should not be forgotten that locomotives lose considerable time each day in switching, unloading, taking on fuel and water, etc. A geared locomotive may be run at the rate of 12 miles or more per hour on ordinary logging railroads, so that it would seem that they should travel 60, 70, 80, or more miles per day. Seldom, however, do they do this, 25 to 35 miles being good work for a locomotive working on spurs or relatively short main lines. Not infrequently they do less than this.

Most operators charge to "Railroad operation" the cost of hauling men to and from their work, hauling rails, ties, ballast, etc., used in constructing and maintaining the railroads, hauling water to logging engines, etc. It is perfectly proper to charge them under this heading or under a special heading. From the standpoint of a timber appraiser, the main thing is that in estimating the cost of railroad transportation he has to consider the amount of track to be built, the amount of material to be used for ballast, whether port-

able or stationary camps are used, and whether water for the logging engines will be hauled, pumped, or supplied by a gravity system.

Labor cost.—A train crew is generally made up of an engineer, fireman, conductor, and brakeman. For a long train two brakemen may be employed.

The following list is intended to approximate the wages—average, high, and low—paid the members of the train crews by the logging companies in the region during the past six years:

Position.	Wages per day.		
	Average.	High.	Low.
Locomotive engineer.....	\$4.00	\$4.50	\$3.75
Fireman.....	3.00	3.25	2.75
Conductor or head brakeman.....	3.50	4.00	3.25
Brakeman.....	3.25	3.50	3.00

The average cost per thousand feet varies greatly. For example, the labor cost per thousand feet for the operation of trains at 20 camps in the Puget Sound region in 1913 was as follows:

Number of camps:	Cost per 1,000 feet.
2.....	\$0. 10-\$. 15
4.....	. 15- .20
10.....	. 20- .25
1.....	. 25- .30
1.....	. 31
1.....	. 40
1.....	. 50

Fuel.—A very considerable item in the cost of operation of logging railroads is the cost of fuel burned in the locomotives. The fuel may be wood, coal, or oil. Wood, as a rule, is not used when coal or oil can be secured at a reasonable price.

On account of the danger of setting fire with sparks from wood or coal, oil makes the most satisfactory fuel. In many cases it is also cheaper. It does not take so long to take on oil as wood or coal, which means a saving of some operating time. Then, a saving in fuel and water is effected, particularly on heavy grades, and the hauling ability is increased, because the steam pressure can be held at a desired point by increasing the oil feed under the boiler. It is not possible to do this with wood or coal, since merely opening and closing the fire box has a marked effect on the efficiency of the locomotive under strained conditions. While bituminous coal is possibly no more satisfactory than wood from the standpoint of the fire risk, it is preferred to wood when it can be secured at a reasonable price. Firemen prefer it because the labor of firing it is not so exhausting. A more even fire can be maintained with it, and less time is lost in taking on coal than wood.

The relative value of the three kinds of fuel is approximately as follows:

One ton of good grade bituminous coal is equivalent to $1\frac{1}{2}$ cords of oak wood or from 2 to $2\frac{1}{2}$ cords of soft wood, and from 130 to 190 gallons of crude oil. For example, in one case 1 ton of coal did the work of 3 barrels of oil. The distance from the camp to the dump was 20 miles. A 60-ton locomotive made two trips per day, the total distance traveled amounting to 80 miles. When hauling 120,000 feet per trip, 6 tons of coal costing \$4.25 per ton were consumed per day, and when hauling the same volume of timber per trip 18 barrels of oil, costing \$1.10 per barrel, were consumed, a saving of \$4.50 per day resulting from the use of oil.

The amount of fuel consumed daily by logging locomotives is extremely variable, depending on the mileage traveled, the loads hauled, the number of heavy grades encountered, and the efficiency of the fireman. Roughly, a logging locomotive burns from 150 to 200 pounds of coal per mile, 150 pounds when the grades do not exceed 2 per cent, 175 pounds when the grades range between 2 and 5 per cent, and 200 pounds when they exceed 5 per cent. These approximations are based on a 50-ton geared locomotive making about 36 miles per day. Using these figures and assuming that 1 ton of coal is equivalent to 3 barrels (126 gallons) of oil, a locomotive burns about $9\frac{1}{2}$ gallons of oil per mile when the grades do not exceed 2 per cent, 11 gallons when the grades range between 2 and 5 per cent, and $12\frac{1}{2}$ gallons when the grades exceed 5 per cent. On the same basis a logging locomotive will burn from 5 to 8 cords of split wood per day.

The cost of oil is discussed under "Ground yarding." Coal delivered costs from \$4 to \$5 per ton. Split wood costs from \$1.75 to \$2.50 per cord when cut into 22-inch lengths and delivered along the track.

Miscellaneous costs.—The cost of lubricants, waste, etc., amounts to from \$0.01 to \$0.02 per thousand feet.

MAINTENANCE OF LOCOMOTIVES AND CARS.

Repairs to locomotives and cars are made by the blacksmith and machine shop department or by some one connected with it. This department also repairs the logging engines and other equipment. Of course, some repairs are made on this equipment by the operating crew. Operators prefer to make the heavy repairs during the slack seasons or during shutdowns.

Investment in shops.—The investment in the blacksmith and machine shops ranges from \$1,000 to \$8,000. Ordinarily it amounts to from \$4,000 to \$5,000. In many cases these shops suffice for both the mill and the logging camp.

Cost.—The cost of the repairs on shop equipment is taken up in the discussion of equipment in this section.

The shop crew ranges from two to seven men. In one large camp having relatively elaborate shops, the crew was as follows: Master mechanic, machinist, car tinkerer, blacksmith, blacksmith assistant, and carpenter.

The following list is intended to approximate the wages paid in the region to the members of this crew during the years 1911–1916:

Position.	Wages per day.		
	Average.	High.	Low.
Master mechanic.....	\$4.50	\$5.00	\$3.50
Carpenter.....	3.50	5.00	3.00
Car tinkerer.....	3.00	3.25	2.75
Blacksmith.....	3.75	4.00	3.50
Blacksmith assistant.....	3.00	3.25	2.75

TOTAL COST OF RAILROAD TRANSPORTATION.

The following gives the total cost of railroad transportation in a few specific cases. In each case the costs are based on a year's output. These cases will serve to show what the total cost consists of, how it varies and why, also the way the items are segregated in the most satisfactory cost statements.

CASE 1.—*Cost of railroad transportation.*

Items.	Cost per thousand feet.
Operation (labor).....	\$0.275
Maintenance of line (labor).....	0.268
Maintenance of locomotive and trucks (labor).....	.122
Maintenance of trucks, repair parts, and materials.....	.04
Maintenance of locomotives, repair parts, and materials.....	.05
Sand (labor).....	.008
Supply house (labor).....	.01
Engineering (supplies).....	.001
Fuel oil.....	.10
Oil, waste, and grease.....	.025
Depreciation on main line grade.....	.10
Depreciation on track supplies.....	.06
Railroad construction spurs.....	.283
Total.....	1.312

The average railroad haul from the landing to the dump was about 4 miles. The first 3 miles was over the main line, the rest over the spurs. The grade on the main line, with the exception of a short stretch, was favorable, averaging about 4 per cent. In places the favorable grade was more than 4 per cent, running as high as 8 per cent for a short distance at one point. There was about 700 feet of adverse grade on the main line, which averaged about 4 per cent.

The cost of constructing the spur lines was below the average, since the surface of the country was relatively smooth and little down timber and brush had to be contended with. The soil, however, drains poorly, which made it necessary to ballast most of the spur railroad with rock ballast. This had to be blasted out of solid rock, broken up by hand, and hauled about 2 miles upgrade. When ballast was not used, the upkeep of the spurs was abnormally high.

A 45-ton geared locomotive worked between the camp and the dump, about 3 miles, hauling about 6 loads per trip and making about 6 trips per day. A 45-ton geared locomotive hauled on the spurs, bringing in three loads at a trip. The spur railroad hauls, of course, varied in distance, but the average haul was about $1\frac{1}{2}$ miles. The adverse grades on these lines did not exceed 4 per cent. A 24-ton rod engine was used to haul the men to and from their work; also to haul supplies, ties, steel, oil, etc.

The cost is based on a year's output of 50,300,000 feet. A portion of the salaries of the foreman, bookkeeper, and timekeeper, and all the salary of the civil engineer, are prorated against the labor cost.

(a) Operation (labor): Three locomotives were operated, with train crews as follows:

	Per day.
Engineer-----	\$5.00
Fireman-----	3.25
Head brakeman-----	4.50
Second brakeman-----	3.75
Engineer-----	5.00
Fireman-----	3.25
Brakeman-----	4.50
Fireman-----	2.75
Engineer-----	3.25

The tracks, main and spur, were kept in better condition as to surface and alignment than is ordinarily the case. No great amount of time was lost in unloading, a train of six cars being unloaded in about eight minutes on the average, sometimes in five minutes. The main locomotive traveled about 36 miles per day and the one on the spurs about 30 miles. From 200,000 to 225,000 feet of timber was hauled per day. The volume of the average load was 5,000 feet.

(b) Maintenance of line (labor): This segregation includes the labor cost of keeping all railroads in good condition as to surface and alignment, keeping ditches open, and taking care of slides. It also includes the cost of considerable ballast. The total mileage maintained at any one time did not exceed $5\frac{1}{2}$ miles, so that the cost of this work seems excessively high. It should be explained that the main line was used for the first time at the beginning of 1917 and that several rather large slides occurred during the year.

(c) Maintenance of locomotives and trucks (labor): This segregation includes the labor cost of repairing the three locomotives already described and 33 sets of trucks. The upkeep of the engine used on the spurs was very high because the engine was not built for the service demanded of it. It was of an early type, having a very light driving shaft, which caused a number of breakdowns during the year.

The regular machine and blacksmith force consisted of the following:

	Per day.
Blacksmith	\$5. 00
Blacksmith's helper	3. 25
Mechanic	5. 00
Car tinkerer	3. 25

During a part of the year, a mechanic assistant and a carpenter were employed; then, too, when a locomotive was in the shop, the train crew assisted with the repairs. It should be stated that the blacksmith and his assistant spent a large part of their time in repairing logging equipment, such time being charged against the cost of upkeep of such equipment.

(d) Depreciation on track supplies: This segregation includes the depreciation on ties, steel rails, bolts, nuts, spikes, rail braces, tie plates, angle bars, etc.

CASE 2.—*Cost of railroad transportation.*

Items.	Cost per thousand feet.
Operation (labor).....	\$0. 19
Maintenance of line (labor).....	. 188
Maintenance of locomotives, cars, and trucks (labor).....	. 155
Maintenance of locomotive repair parts and materials.....	. 06
Maintenance of cars and trucks, and materials.....	. 05
Fuel oil.....	. 10
Oil, waste, grease, and packing.....	. 02
Depreciation on main-line construction.....	. 09
Depreciation on track supplies.....	. 04
Ties.....	. 04
Spur railroad construction (labor).....	. 29
Spur railroad construction (powder).....	. 03
Total.....	1. 233

The year's output on which this cost is based was 37,788,000 feet, the average output per day amounting to about 150,000 feet.

A portion of the salaries of the foreman and bookkeeper, and all the salary of the civil engineer are prorated against the labor cost.

Two geared locomotives, one 33 and one 42 ton, were used to haul the logs and do miscellaneous work about the camp, including railroad construction. The haul from the landings to the dump and the camp (buildings) had practically a water grade, the 42-ton

locomotive at times handling 18 loads over this portion of the road. The average grade on the two miles of main line between the camp and Spur 1 (woods' terminus of main line) averaged $5\frac{1}{4}$ per cent, the maximum grade amounting to 6 per cent. The 42-ton locomotive pulled four empty flats from the camp to the siding. The heaviest grades on the spurs amounted to 9 per cent. The average spur haul from the landings to the main line was about 1 mile. Twenty flats (length, 41 feet; capacity, 80,000 pounds) and six sets of trucks were used. Oil was burned as fuel.

The 42-ton locomotive worked on the main line between the dump and Spur 1, a distance of about 5 miles; the 33-ton engine worked on the spurs. In the morning the 33-ton locomotive would move four empty flats from the camp to the siding at Spur 1. The 42-ton locomotive averaged four or five trips per day between the dump and the siding at the camp, and roughly twice as many trips between the latter siding and the siding at Spur 1. The two brakemen, with the assistance of a man regularly employed at the dump, unloaded the cars with log jacks.

(a) Operation (labor): The train crews consisted of the following:

42-ton :	Per day.
Engineer.....	\$5.00
Head brakeman.....	4.25
Second brakeman.....	3.75
33-ton :	
Engineer.....	4.50
Head brakeman.....	4.75
Second brakeman.....	3.75

The difference in the wages was not due to differences in the work, but rather to length of service with the company.

(b) Maintenance of line (labor): This segregation includes the labor cost of keeping all roads in good condition as to surface and alignment, keeping ditches open, taking care of slides, and hauling and digging gravel. It includes the upkeep of about 6 miles of line. During the year a large portion of the track was ballasted with gravel, the ballast being secured from the bed of a river with a power scraper. There are a large number of heavy cuts, and the formation is such that slides occurred frequently during the wet season.

The section foremen were paid \$3.50 per day; the hands, \$2.50 per day.

(c) Maintenance of locomotives and cars (labor): This segregation includes the labor cost for repairing 2 locomotives, 20 flat cars, 6 sets of trucks, and 2 gravel cars.

The regular machine and blacksmith crew consisted of the following:

	Per day.
Blacksmith	\$5.00
Blacksmiths' helper	3.50
Machinist	5.25
Machinist's helper	3.25
Car tinkerer	3.25
Carpenter	3.50
Second carpenter	3.00
Rigging man	3.40

This crew, in addition to repairing the locomotives, flat cars, and trucks, made the repairs on the logging equipment, the labor cost of which was \$0.077 per thousand feet.

CASE 3.—*Cost of railroad transportation.*

Items.	Cost per thousand feet.
Operation (labor)	\$0.12
Maintenance of trucks (labor)	.018
Maintenance of locomotive (labor)	.01
Spur construction and maintenance (labor)	.262
Maintenance of trucks (labor, repair parts, and materials)	.02
Maintenance of locomotive (labor, repair parts, and materials)	.015
Fuel wood	.05
Oil, waste, grease, and packing	.01
Depreciation on equipment and track supplies	.14
Miscellaneous	.03
Log freight	1.25
Total	1,925

In this case it was possible to locate the railroads practically any place without encountering heavy grades, since the ground for the most part is relatively level. The spur lines were ballasted and kept in good alignment.

The company had been operating about 3 years and at the time the above costs were secured had a cut of about 7 years ahead.

The year's output on which these costs are based amounted to 50,000,000 feet.

(a) Operation (labor): This segregation includes the cost of operating a 52-ton geared locomotive on the spur lines, hauling the logs from the landings to a siding at the camp. The logging engines were working on two spurs; one about 1 mile from camp, the other two about 2 miles from camp. To take care of the output of the camp, which was about 240,000 feet per day, it was necessary for the train crew to work overtime. The logs were hauled from camp to Puget Sound, a distance of about 12 miles, by contract, at a rate of \$125 per thousand feet. This rate included the cost of dumping, sorting, and rafting. The train crew consisted of the following:

	Per day.
Engineer-----	\$4. 00
Fireman-----	3. 25
Brakeman-----	4. 00

(b) Maintenance of trucks: This includes the maintenance of 56 sets of trucks.

RAILROAD INCLINES.

Inclined tracks for lowering logs are becoming an important engineering feature of logging operations. They have been used a long time in the region, but only in connection with short inclines of light grades and where ordinary logging engines furnished the power to raise or lower the roads. It is only within the past six years that operators began to consider it practical to lower loaded cars for long distances over heavy grades and with specially constructed equipment.

Heretofore large bodies of timber standing on plateaus or on mountain sides high above the main-line railroad were reached by a series of switchbacks or detours. If the amount of timber did not make such a railroad practical, chutes were used. In either case the expense of moving the timber was large. At the present time long inclines are used to transport logs from plateaus to the lower levels, the incline in such cases connecting two systems of railroads, one on the plateau and the other on the flat below; or to lower logs cut on mountain sides, such inclines running practically straight up the slope, with lateral spurs radiating from them.

The roadbed of inclines does not demand the heavy construction required where trains pass, because there is no pounding action such as is produced by a locomotive. An uneven grade is not a serious handicap unless there are portions where the grades are so gentle that cars will not be pulled to the foot of the incline by gravity. While it is desirable that inclines be built in a straight line, it is not strictly essential.

There are two systems of inclines in use; the one-way incline, in which one or more loaded cars are lowered on the down trip, the empties being returned on the up trip; and the counterbalanced system, in which a loaded car descends as the empty car ascends.

COUNTERBALANCED INCLINE.

The first long railroad incline to be used in a logging operation on the Pacific coast is of the counterbalanced type. This incline was put in operation in 1912, and it is still the longest incline in use in the region. It has a length of 8,000 feet and a fall of 3,100 feet, which means that the grade averages 45 per cent. The grade is very uneven, varying between a maximum of 78 per cent and a minimum of 10 per cent.

Another incline of this type was put in operation in Washington in 1914. A brief description of this incline and the method of its operation follow:

From the sawmill the logging railroad follows a valley for a distance of $2\frac{1}{2}$ miles on a broken grade, the maximum grade being $3\frac{1}{2}$ per cent. At the incline end of the railroad there is a 1,600-foot tangent, which breaks into a 24-degree curve. This curve connects with a short stretch of tangent track which forms the foot of the incline. At the foot of the incline there is a passing track for the storage of empty cars. This track, being connected with the main line at two points and having a 4 per cent grade, permits the empties to be dropped out on the main line toward the incline by gravity.

The incline is 5,300 feet long and straight for its entire length. It has a vertical rise of 1,500 feet, the maximum grade being 56 per cent, the minimum 15 per cent. The latter grade occurs at the passing point.

Starting at the bottom of the incline, there is a single track until the passing point is reached. From this point to the top of the incline there is a double track. At the upper end of the incline the tracks are laid 6 feet $8\frac{1}{2}$ inches apart, center to center, except at the passing point in the middle of the incline, where they are 12 feet apart, center to center. This arrangement insures ample clearance for the rope and permits the transportation of camp buildings, logging engines, and other equipment, up or down the incline, on cars.

At the top of the incline there is a gravity siding on which the empties run. This siding branches from the incline proper and runs along below the logging road for a short distance before connecting with it.

The hoisting line passes through sheaves on the top of a tower or headworks set at the top of the incline near the hoisting engine. These sheaves, six in number and set tandem, equalize the strain on the line. The sheaves are not overloaded, each one being calculated to carry a load of 2,000 pounds, one-sixth of the downward pressure of the line at this point.

The lowering engine is located 350 feet back from the head of the incline and 250 feet from the headworks. It is mounted on a 55-foot sled, which is set level in a pit. A timbered bulkhead is set between the front end of the sled and the dirt wall of the excavation. The runners of the sled, together with the hold-down weights for the brakes, are embedded, thus insuring a very substantial setting.

The hoist consists of a large gypsy drum, equipped with suitable brakes to control the load in its descent, the motive power being furnished by 11 by 13 inch engines of the reversible type. It is equipped with two sets of gears, one set having a gear ratio of 5 to 1, the other 15 to 1. This arrangement gives a high speed—900 feet per minute—

when loaded cars are descending the incline, and a low speed for pulling up locomotives, yarding engines, etc. There are two sets of brakes—one operated by hand, the other by steam. This minimizes the danger of losing control of the load. Both brakes have tremendous holding power. The steam brake is so arranged that in the event of the steam line's becoming disconnected, the brake would be automatically thrown on, thus stopping the engine. This function of the brake is controlled by a 1,400-pound weight. In other words, when the engine is cold the brake is set, it being necessary to use steam to lift the weight. The hoist is strongly made throughout, weighs approximately 35 tons, and costs \$6,500 f. o. b. Portland.

The lowering line is wrapped around the gypsy four times, so that either end can be moved up or down the incline. It consists of $1\frac{1}{2}$ inch Warrington construction wire rope, which has an approximate strength of 98 tons. The stress on the rope in operation amounts to about 29 tons, giving a factor of safety of 3.35. A lubricant, consisting of pine tar and skid oil, is applied to the line three times a week. This keeps the line in good condition and greatly prolongs its life.

It has been pointed out that this line leads through sheaves on a tower at the head of the incline. To reduce further the friction and wear on the line, suitable rollers—10 in number—are placed at points where heavy breaks in the grade line occur and where the line comes in contact with the ground. These rollers are made of manganese steel, with the ends higher than the center, to keep the line traveling in the center of the track.

In hooking the load to the incline cable, a bridle with a choker hook spliced in each end is placed over the load. A long strap with an eye splice in each end is then passed under the load, through the chokers of the bridle, and back over the draw head of the flat car. A heavy clevis is used to fasten the incline cable to the bridle. To do away with any side pull that may result from the tightening of the cable, a short piece of chain is fastened around the draw head over the bridle ends. This brings the incline cable pull to the center of the track. If this were not done, the line would not travel in the same place each time, and so it would be impracticable to place track rollers.

Electric bells, located at the top and bottom of the incline, are used for a signal system. These are supplemented by telephones at the bottom, at the passing track in the center of the incline, and in the lowering engine house, thus affording communication for the entire length of the line and increasing to a great degree the efficiency and safety of the operation.

The operation of the incline is briefly as follows: A $9\frac{1}{4}$ by 10-inch yarding engine, located about 75 feet from the hoist from which it

receives its steam, hooks on to an incoming load and spots it on the incline proper. This spotting engine also kicks the empties over the switch and upon the gravity spur track. The descending load brings up the empty car—standard Northern Pacific flats—their passing taking place at the middle of the incline. The load is under brake control for the entire distance, it being necessary to use steam only at starting. A trip from the headworks is made in six minutes. A daily output of 50 cars, or 250,000 feet, could be readily handled over the incline in a 10-hour working day, this being at the rate of five cars per hour, or one car in twelve minutes.

The total cost of the incline—construction, installation of equipment, equipment, etc.—was approximately \$22,250. This cost may be itemized as follows:

1. Cost of clearing right of way for incline proper and gravity sidings, top and bottom, also site for headworks and hoist	\$500
2. Cost of grading right of way	2,000
3. Cost of laying and surfacing track, dirt ballast was used	800
4. Cost of headworks, including labor, material, equipment, etc.	150
5. Cost of installing hoist, including labor and material, etc.	1,000
6. Cost of ties	900
7. Cost of steel and fixtures (60-pound steel, at \$40 per ton)	4,200
8. Cost of track rollers	400
9. Cost of lowering line (5,800 feet of 1½-inch line)	3,200
10. Cost of lowering engine, f. o. b. Portland	6,500
11. Engineering	500
12. Miscellaneous (labor, equipment, freight, etc.)	600
13. Spotting engine (second hand) with equipment	1,500
Total cost	22,250

The cost of operation, including depreciation, maintenance, supplies, etc., is estimated as below. In this estimate it is assumed that 125,000 feet of timber is handled daily over the incline.

	Cost per 1,000 feet.
Labor (includes an engineer at \$3.75, a hooker and unhooker at \$3.00, and a chaser at \$2.75)	\$0.10
Maintenance of grade and ties (labor and material)	.02
Maintenance of lowering engine	.01
Wire rope	.05
Fuel	.04
Lubricants	.01
Depreciation on improvements	.06
Depreciation on hoist, steel, and other equipment	.04
Miscellaneous	.01
Total	0.34

ONE-WAY INCLINES.

There are two classes of one-way inclines: The single-line system and the two-line system.

SINGLE-LINE SYSTEM.

The single-line system has been most used by logging operators on short inclines. That it is adapted for rather long hauls, however, is indicated by the following:

An operator was confronted with the problem of opening up a body of timber, estimated at 150,000,000 feet, which stood on a plateau high above the existing railroad system. To extend the railroad to reach this timber would have involved the constructing of a series of switchbacks having a total length of 4 miles and costing \$32,000; so an incline was built. It was determined that a special lowering engine would be too expensive, considering the fact that this type of engine could be used for no other purpose. A combination engine—one that could be used first for incline purposes and later as a road engine—was selected. This engine has 12 by 14 inch cylinders and a 72-inch boiler, the arrangement permitting the fore end to be converted into a standard road engine with a few changes. The main drum is fitted with a 10-inch shaft, also with a special brake.

The incline is built on a straight line, and has a length of 2,000 feet and a maximum grade of $66\frac{1}{2}$ per cent. Wire rope $1\frac{1}{2}$ inches in diameter is used for a lowering line.

The incline has a capacity of 25 cars per day, the average load amounting to about 7,600 feet. One truck is lowered at a time. An average round trip takes 15 minutes, 4 minutes for lowering the load and 3 minutes for returning the empty to the summit. The other 8 minutes are taken up in hooking and unhooking loads, and in idle time.

The lowering engine cost \$6,500; the grading, track laying, etc., \$4,700.

TWO-LINE SYSTEM.

The first incline of the two-line type was installed in 1914. The logging manager who devised the scheme was confronted with the problem of removing the timber from 9 square miles of mountain-side the lower boundary of which was about 1,200 feet above the main line railroad that ran along the base of the slope. The timber along the bottom of the slope had been logged to this railroad by the ordinary ground yarding method. To open up the timber on the mountainside with a system of railroad spurs of the usual type would have meant the tying up of a large quantity of steel rails, and very long, heavy switching; or, in other words, a heavy investment and high operating cost. It was decided that the topography of this particular area would permit the use of a railroad incline from which lateral spurs could be projected on practical grades, or grades on which a geared locomotive could be operated.

Largely because of the shape of their holdings and the topography of the area, the company had to construct three inclines. These inclines proved very satisfactory. In length they ranged from 4,000 to 6,000 feet. The grades varied. The grades on the first one ranged from 6 to 18 per cent, with the exception of 600 feet of $1\frac{1}{2}$ per cent grade. In the case of one of the others, the maximum grade was 30 per cent. While the aim is to build these inclines on a straight line, or nearly so, it is not always practical to do so. For example, in one

case 1,200 feet of the incline was on a 12 degree curve.

The incline proper is constructed as in the case of an ordinary railroad spur. There is a siding for the accommodation of empties at the bottom of the incline, also at points on the incline where the lateral spurs, about one-fourth mile apart, connect with it. See figure 70.

The power is furnished by an 11 by 13 inch hoisting engine of the reversible type, which is placed at the top of the slope (fig. 70). This engine, which has a drum capacity of 12,000 feet of $1\frac{1}{8}$ -inch cable, is mounted on a sled and can be moved

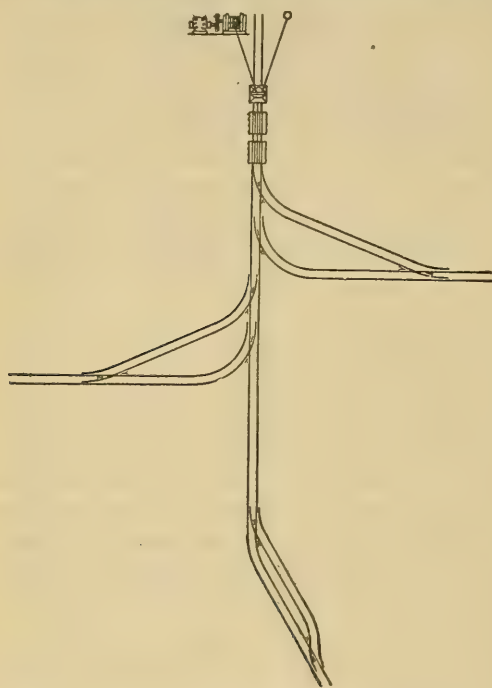


FIG. 70.—Location equipment and tracks, two-line railroad incline.

from one location to another in the same way as the ordinary ground yarding engine. It has ample power to handle five loaded cars on a 40 per cent grade.

When the system is in operation, the lowering line leads from the engine, which is placed to the left of the incline, then through a block on the lowering car, and thence to a stump or deadman near the engine but on the opposite side of the incline (fig. 70). This doubles the pulling power of the engine.

The loaded cars, where the grade will permit, are attached one to the other in the usual way, with the head load attached direct to the lowering car (fig. 71) by a tag line. Where the grade is steep, the method shown in figure 72 is used. The lowering car has a heavy steel frame and is 16 feet long. A large compound block (fig. 73), tri-

angular in shape and composed of three 3-foot sheaves (fig. 74), is mounted on its deck. The lowering cable passes around the sheaves and over two rollers mounted on brackets on the side of the car. This arrangement gives a clearance of 14 feet between the moving and

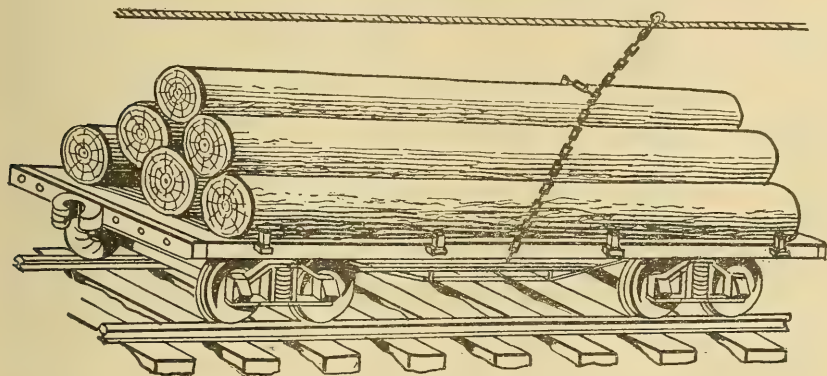


FIG. 71.—Loaded car, two-line railroad incline.

dead line. This car can be equipped with a gasoline engine, thus making it self-propelling.

The lowering line never touches the ground. The dead section of it rests on skids laid along one side of the track. These are placed about 20 feet apart and at right angles to the track. The moving

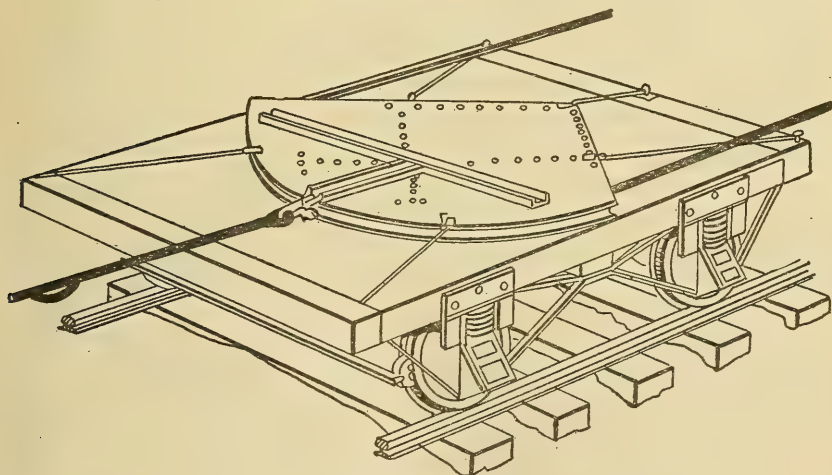


FIG. 72.—Lowering car, two-line railroad incline.

section of the line on the other side of the track leads over ordinary sheaves placed about 100 feet apart, the sheaves working in stands that have flared sides. On the inside of the curves the section of the line leads over light twin-road rollers, while on the outside of curves the dead section of the line is held in place by brackets, which auto-

matically release and pick up the line when the lowering car passes that point.

The operation of this system is as follows: The friction on the hoist is released and the weight of the lowering car takes the line to the bottom of the grade, except where the grade is slight. Over such grades the car propels itself by means of its gasoline engine. The lowering car is attached to the empties, and the hoist pulls them up the incline. The lateral spurs being reached, the hoist is stopped, and the empties are dropped on a siding where the locomotive operating on that spur can get them. When the cars are loaded a locomotive takes them to the point where the spur joins the incline. The hoisting car is then lowered, as before, and is used to pull the loaded cars up the grade past the switch and upon the incline ready for their trip down the incline.

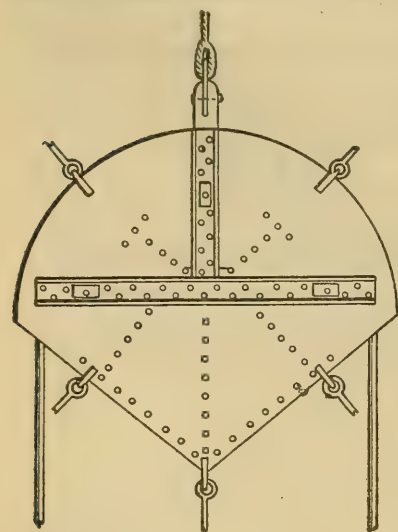


FIG. 73.—Hoisting block, two-line railroad incline.

When operating the 4,000-foot incline, which had a maximum grade of 17 per cent, four cars scaling 32,000 feet were lowered at one time, and it was felt that 40,000 feet would not have constituted an excessive strain on the engine or line. The company, however, made a practice of lowering only three loaded cars and taking back six pairs of empty trucks, since their operation did not demand that more loaded cars be handled at a trip. It never took more than 10 minutes to lower the three loaded cars. During the time this incline was in use no cars were derailed or logs lost. In the case of the 6,000-foot incline, which had a maximum grade of 18 per cent and a 12-degree curve, 26,000,000 feet of timber was lowered without a derailment. On this incline as many as five cars, or 50,000 feet, were lowered at a trip. In the case of the 4,800-foot incline, which was laid on a

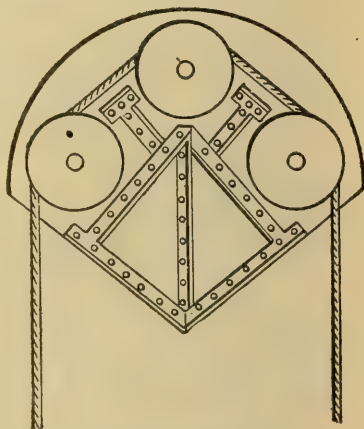


FIG. 74.—Hoisting block (top plate detached), two-line railroad incline.

straight line and had a maximum grade of 30 per cent, two cars were lowered at a trip, 40 cars being lowered in a day.

The operating labor cost per thousand feet varies, of course, with the average amount of timber lowered on the incline per day, the total daily labor cost being to a great extent fixed. The total daily labor cost amounts to about \$13 per day, as follows:

	Per day.
1 engineer.....	\$3. 50
1 fireman.....	2. 75
1 brakeman.....	3. 50
1 brakeman.....	3. 25
Total	13. 00

The life of the lowering line is not known, since no lines have been worn out so far. One line has been used to lower 50,000,000 feet, and it seems that it is not more than one-half worn out.

The fixed investment in the incline equipment proper is approximately as follows:

Lowering engine, together with the sled and small equipment used around the engine.....	\$7, 350
Lowering car.....	1, 500
Set of rollers.....	500
12,000 feet 1½-inch cable.....	3, 500
Miscellaneous equipment.....	200
Total	13, 050

UNLOADING.

Logs as a rule are unloaded, or dumped, into mill ponds, streams, or tidewater. Very small operators sometimes unload logs to, and store small quantities on, the land. The latter is a very unusual practice in the fir region of the Pacific coast.

A number of different methods are used. Only two principles, however, are involved. The logs may be pushed from cars, or in connection with a superelevated track they may be pulled from the cars by gravity.

As a rule, cars are unloaded by means of a rollway, or dump, and an unloading machine. When the logs are dumped into a mill pond or stream, the dump, serving as a part of the railroad track, is generally built along the bank. To dump logs into tidewater it is necessary to extend the track over the water.

The aim of all operators, of course, is to unload logs as cheaply as possible. The cost of this step, however, must be considered in connection with the cost of other steps in the logging operations. In other words, a nice balance should exist between the total cost of unloading logs and the total cost of transporting the logs from the landings to the dump and the cost of booming and sorting. This is

particularly true of the balance as it relates to the cost of railroad transportation. It is obvious, therefore, that the method, equipment, and improvements to be used in a given case depend on a number of factors. There is also, of necessity, a relation between the character of the improvements and equipment and the method used.

As a general thing the train crew constitutes all, or the major part, of the help used in unloading. This means that the train is held at the dump until the logs are unloaded, the time depending on the speed of the method. When the railroad haul is short and the output small, a slow method with simple improvements and equipment is the cheapest, all things being taken into consideration. If the logging train is crowded because of a long haul or a large output, a more elaborate method may be necessary than may seem to be justified by the unloading operation in itself.

If the water is deep and has a current, the dump may have only one track and be comparatively short, making it possible to use a stationary unloading rig satisfactorily, since the logs will float away as soon as they are dumped. While still, deep water does not greatly increase the difficulty of unloading logs, it does constitute a drawback. If logs are dumped rapidly into still, deep water, the disturbance caused by their falling will not be sufficient to keep the logs from piling up, necessitating in some cases the employment of an extra man. Shallow water is a serious drawback. Where the unloaded logs do not float away, more or less breakage results when the logs are thrown on the pile that forms. This is especially true in the case of cedar logs. Then, too, a jam of this kind increases the work of the boom man. Under such conditions, a long dump in connection with a portable unloading machine, or some other device for unloading the logs at different points along the dump, is generally used.

DUMPS.

Where the track is built along the bank of a stream or pond, an inclined dump, over which the logs roll into the water, is generally used. The length, breadth, pitch of skids, strength, etc., depend on the topography and soil formation of the location, the size of logs, the method of unloading, etc. The dump may consist of a framework composed of three parallel sets of stringers, spaced about 8 feet apart, which extend to the water's edge for 60 feet or more. The outer stringer, possibly the middle, projects over the water's edge and is supported on piling or timbers that rest on solid bottom, while the other stringers are supported on round or square uprights placed from 4 to 6 feet apart. Heavy timbers, generally round, are placed on top of and at right angles to the stringers. These timbers are generally laid flush, forming an unbroken floor, with a pitch of

from 15 to 25 degrees. The upper ends are placed slightly below the level of the car bunks. As a rule, every third or fourth timber is shod with railroad iron. The total cost of a 60-foot dump of this type, including labor, material, supplies, etc., and excluding the cost of the track, is about \$500.

Quite often, as has been indicated, the dump is built on piling over the water. The trestle, for the dump proper, may be long enough to accommodate 20 cars or more. An additional length of trestle is usually necessary to get the cars to deep water. To protect the trestle from falling logs, a row of piling is driven flush with the ends of the ties and far enough from the rail to permit the passage of cars. This row of piling, forming an unbroken wall, is capped with a brow skid, the top of which is a little below the top of the car bunks. It is usually faced with a similar row of piling, the second row being beveled off at the top. If a stationary unloading machine is to be used, the dump proper is not more than 70 or 80 feet in length and placed at the most advantageous point, taking into consideration the depth of the water and the arrangement for sorting and rafting.

The cost of dumps of this character varies greatly, for the most part because of the differences in the type, size, and location. The method of unloading also influences it. With these factors known, it is possible to estimate the cost with substantial accuracy. The cost data given under the head of "Railroad transportation" will assist in making an estimate. Further assistance can be secured from cost data published for the use of engineers. The price of piling delivered to a given location, the contract price of driving, and the cost of sawed timber can be learned. If the trestle is built over salt water, the maintenance cost will be much higher than if it is built over fresh water.

PRICE OF PILING.

The price of piling varies from 6 1/2 to 10 cents per linear foot. Douglas fir is usually used, although hemlock is sometimes used in small quantities. The selling prices of winter-cut Douglas fir piling, with 10-inch tops, delivered to the tidewater of Puget Sound, was approximately as follows in April, 1916:

	Cost per linear foot.
25 to 40 foot piles.....	\$0.080
45 to 50 foot piles.....	.085
55 foot piles.....	.090

The specifications for piling may include the following: That piles 20 to 30 feet in length shall have 9-inch tops; that piling 30 feet or over in length shall have 10-inch tops; that the piling shall not be less than 14 inches nor more than 22 inches in diameter at a point 6 inches from the butt end; that there shall not be more than 1½

inches of the sapwood at the top of the piles; and that a line drawn from center to center shall lie within the pile.

COST OF DRIVING PILING.

Pile driving is usually done by contract. Contract prices vary, for the most part with the size of the job, the distance the equipment has to be moved, the character of the structure, the length of the piling, and the character of the formation the piles are to be driven in. When the piling is driven in relatively deep water, the contract price for driving amounts to about \$1.50 per pile.

Contractors figure that the cost of driving amounts to about \$1 per pile, and that their profit should amount to about \$0.50 per pile. The following shows the approximate daily cost per pile-driving crew to the contractor.

	Cost per day.
Labor:	
Foreman	\$5. 00
Engineer	4. 00
Loftman	3. 00
Boom man	3. 50
Roustabout	3. 00
Total	18. 50
Pile driver:	
Fuel and other supplies, maintenance and depreciation of equipment, interest on investment, etc	10. 00
Grand total	28. 50

A crew will drive from 25 to 30 piles in a day.

LIFE OF PILING.

The average life of piling in salt water under ordinary conditions is from 3 to 4 years, the maximum 5 years. Where the water is less salty, the life of piling is longer. For example, at or near Bellingham, in the waters of Bellingham Bay, it is about 7 years. This is due to the fact that the Nooksack River discharges a large volume of fresh water into this bay, hindering the rapid growth of the animal life that is so injurious to piling. There are other cases where the life of piling driven in salt water is longer than this.

COST OF PILE-BENT TRETTLES.

The cost of trestles is discussed in works dealing with the economics of engineering construction. The cost of five-pile-bent trestles of standard construction when built over the tidewaters of the region, the piles averaging about 40 feet in length, amounts to about \$6 per running foot. This is the complete cost exclusive of the rails.

The cost of a bent with 15-foot centers is approximately as follows:

5 piles, driven and capped (material and labor), at \$10 per pile-----	\$50.00
2,200 feet of timbers in place, including labor and material (timber, iron, spikes, bolts), at \$19 per thousand feet-----	41.80

Total cost per bent-----	91.80
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The following indicates the character, size, and amount of material used:

- 5 piles, averaging 40 feet in length.
- 1 cap, 12 by 14 inches by 14 feet.
- 2 sway braces, 3 by 10 inches by 14 feet.
- 6 stringers, 8 by 16 inches by 15 feet.
- 12 ties, 6 by 8 inches by 12 feet.
- 3 ties, 6 by 8 inches by 14 feet.
- 2 guard rails, 6 by 8 inches by 15 feet.
- 2 planks, 2 by 12 inches by 15 feet.
- 30 boat spikes.
- 6 bolts, $\frac{3}{4}$ by 11 inches.
- 4 bolts, $\frac{3}{4}$ by 19 inches.
- 4 bolts, $\frac{3}{4}$ by 29 inches.
- 5 drift bolts, $\frac{3}{4}$ by 24 inches.
- 4 drift bolts, $\frac{3}{4}$ by 32 inches.

METHODS.

SUPERELEVATED RAIL.

A number of operators unload their logs very satisfactorily by means of a superelevated track. The railroad track is laid parallel with the dump and so that the top of a car in passing will be about 6 inches away from it. The outer rail is elevated from 12 to 16 inches, thus throwing the side of the car next the dump at a lower level. Most of the logs will roll from the car into the water when the car stakes are removed, the dogs on the car bunks lowered, or the binder chains loosened. The remainder of the logs are rolled off the car by means of logging jacks, levers, or makeshift gill pokes. This is one of the simplest methods of unloading, being extensively used, especially where the output is small and the logs are dumped into a mill pond. It may be used with all types of dumps.

LOGGING JACKS.

The depth of the water and the height of the track above the water may make it necessary to dump the logs at different points along the dump rather than at one point. Under such conditions, if the output is small or if the train crew is not crowded, it may be economical for the train crew to unload the logs with logging jacks. To facilitate unloading with this method, the track is slightly super-elevated, which results in some of the logs rolling from the cars

when the car stakes are cut or tripped or the binder chains loosened. The remainder are pushed from the cars with logging jacks.

At one camp where unloading is done with this method, a crew of three men—two brakemen and a dump man—unload eight cars, averaging about 7,500 feet to the car, in about 30 minutes. The dumping is seldom accomplished in less than 20 minutes, and it sometimes takes an hour. The cars are equipped with patent stakes. Considerable time is lost because the brow skid is too high. The logs average about 2,000 feet in volume.

TILTING DUMP.

The tilting dump is used by a few operators. The dump is usually built in paired sections, each 40 feet in length, with 30 feet of stationary track between. This arrangement permits logs of any length to be dumped. Two cars loaded with 40 foot logs can be dumped at the same time. When the logs are longer, one load is dumped at a time, a truck being "spotted" on each of the two sections, which are tripped simultaneously.

Piles capped with timbers form the foundation. The roller timber—a stick 42 feet long and 20 inches square—and two stringers, supporting a floor of ties and the latch stringers, form the platform of the dump. The five latch timbers on each section of the dump extend about 2 feet beyond the ties on the land side and are fastened down by means of iron latches. This arrangement holds the sections level when the loads are run on. The center latch timber, which is known as the trip timber, is longer and larger than the others, being 36 feet long, 9 by 18 inches at one end, and tapering to 9 by 12 inches at the other, or latch, end. The roller timber works on heavy cast-iron chains which rest on the sills.

The operation is simple. When the cars are spotted, the chains taken down, and the latches knocked off, gravity causes the dump to revolve 15 degrees on its axis, rolling the logs from the cars. This action is due to the fact that the center of the track is placed about 3 inches from the center of the roller timber on the water side. The dump is brought back into position by the workmen walking out on the trip timber. Loads heavy on the land side will not trip the dump. Under such conditions, the tilting action is started by lifting up on the trip timber. Slabs will not always roll off at the inclination provided, making it sometimes necessary to use a gin pole and parbuckle line. The design of the dump is shown in a general way in figures 75 and 76.

At one camp which uses this method, three men—two brakemen and the locomotive fireman—dump the logs at the rate of one car per $2\frac{1}{2}$ minutes, a large part of this time being consumed in taking down and

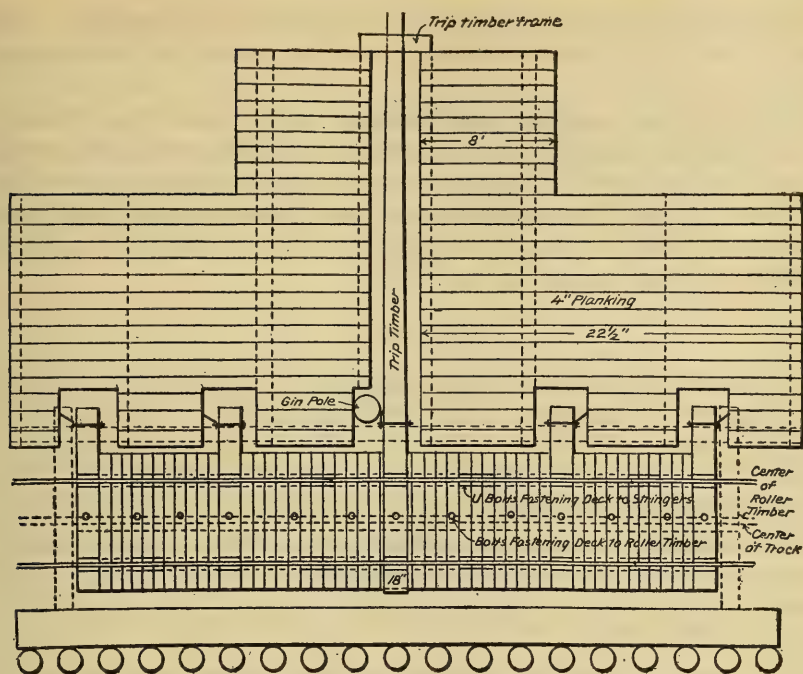


FIG. 75.—Floor plan of a tilting log dump.

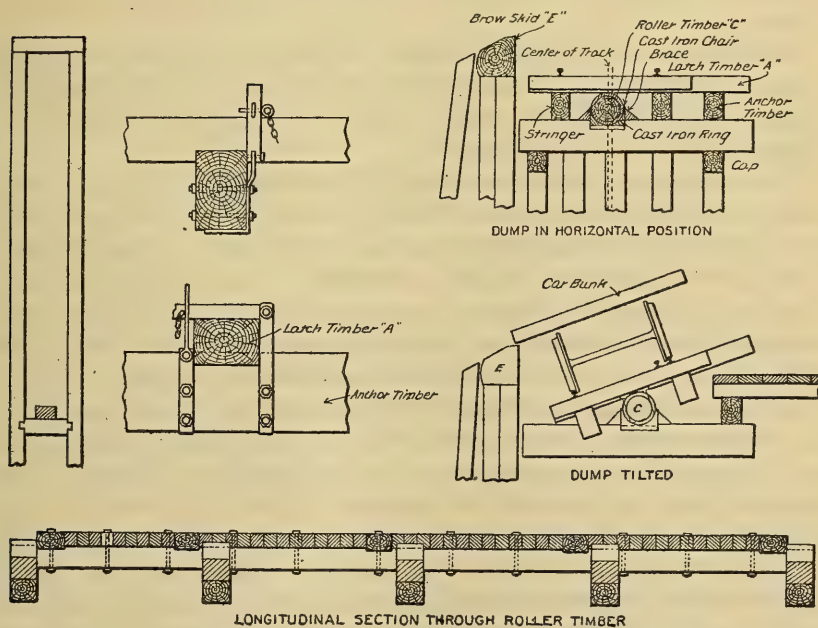


FIG. 76.—Details of a tilting log dump.

putting up the binder chains. If the trucks were equipped with patent stakes, the time consumed in unloading would be considerably less.

The cost of dumps like that described above varies with different locations and different soil formations. Under ordinary conditions, the cost, not including the approaches, should range from \$2,000 to \$2,500. The maintenance of one of these dumps for 7 years cost about \$300 per year. During this time the dump was practically rebuilt through maintenance.

GIN POLE.

A number of operators unload logs under conditions that render a gin pole and parbuckle line a practical method. The gin pole, which is about 35 feet in height, is erected along the track on the land side, with the $\frac{7}{8}$ -inch parbuckle line leading through a sheave block at the top of the pole. In unloading, one end of the line is passed under the load to the opposite side of the car and fastened to the brow skid. When the line is tightened by power applied at the other end, the load is raised from the car bunks and pushed from the car. With this method a mast, or pole, to which a cross arm is braced about 20 feet from the track, is used in most cases instead of a gin pole, the parbuckle line leading through a sheave block at each end of the cross arm. The cross arm extends over the track about 8 feet.

The logs are dumped at one point, which, as has been suggested, is not practical under all conditions. Some operators eliminate this objectionable feature by using a number of gin poles erected car-lengths apart along the dump.

The power as a rule is furnished by the locomotive, the hand work being done by the train crew. When a number of gin poles are used, the locomotive is the only practical source of power. In some cases, where it is desirable to unload as quickly as possible, the power is supplied by an ordinary logging engine, generally an old one, necessitating the employment of an unloading engineer in addition to the regular train crew. If the logs are unloaded in a pond near the mill, the power may be furnished by a hoist, the steam being furnished by the mill. In one case a $6\frac{1}{4}$ by 10-inch single-drum hoist is used, the machine being operated by the locomotive fireman. The engineer spots the cars and the brakemen adjust the parbuckle line. When the dump is located near a power plant, an electrically driven hoist may furnish the power. In one case, a 30-horsepower Westinghouse motor, connected with the drum shaft by a double-reduction gear, is used. The two drums are operated on this shaft by ordinary logging-engine frictions. One drum carries the parbuckle line; the

other, which can be operated independently, is used for miscellaneous purposes.

This method is slower when the locomotive is used to spot the cars and to furnish the power in unloading than when the power used to operate the parbuckle line is furnished by a separate engine. With the former source of power it takes from 2 to 3 minutes to unload a car of logs; with the latter, from 1 to 1½ minutes.

GILL POKE.

(1) One of the simple gill-poke devices is as follows: The track on the entire length of the dump is slightly superelevated. Parallel to the track on the land side, and about 5 feet above the level of the track, there is a timber with notches cut at proper distances. The arm of the poke is a stick of wood 4 by 3½ inches by 6 or 8 feet, which is shod with a sharp steel prong at the pointed end and has a collar at the blunt end. In operation the pointed end of the poke is placed against the logs and the heel is inserted in one of the notches in the timber, the positions of the poke being such that it will push the logs from the car when the car is put in motion. Thirty-two cars, containing 150,000 feet, have been unloaded with this method in 20 minutes.

(2) Another gill-poke device is shown in figure 77*a, b*. The top of the center pile, to which the arms, or sweeps, are hung, is about 12 feet above the level of the track. The arms are about 30 feet in length, the center pile being so located as to enable them to reach across the track when the machine is in operation. The four piles which surround the center piling are bound together with a 1-inch wire cable and serve no other purpose than to brace the center pile. In the case shown in the figure, the distance from the arms to the ground is about 12 feet. If the distance is greater than this, additional piling is necessary. There are 2 or 3 inches of play between the center piling and the points where the arms are joined together, making it possible to raise or lower an arm preparatory to engaging a load of logs. A heavy plate of iron is bent half around the center pile at the point where the arms press when in operation. With the chock blocks tripped, the train crew can unload several cars of logs per minute. Under ordinary conditions the total cost of this device installed ranges from \$600 to \$800.

(3) Two arms are sometimes used. In one case they are 17 feet long and made of channel and angle iron. They are 18 inches wide except at the ends, where they are made 36 inches wide to give a broad surface to repel the logs. They are bolted opposite to each other on a 24-inch journal, and braced with a turnbuckle. The arms and journal are set on a shaft 11 feet long and 10 inches in diameter, cut down to 8 inches where the journal is fastened to admit

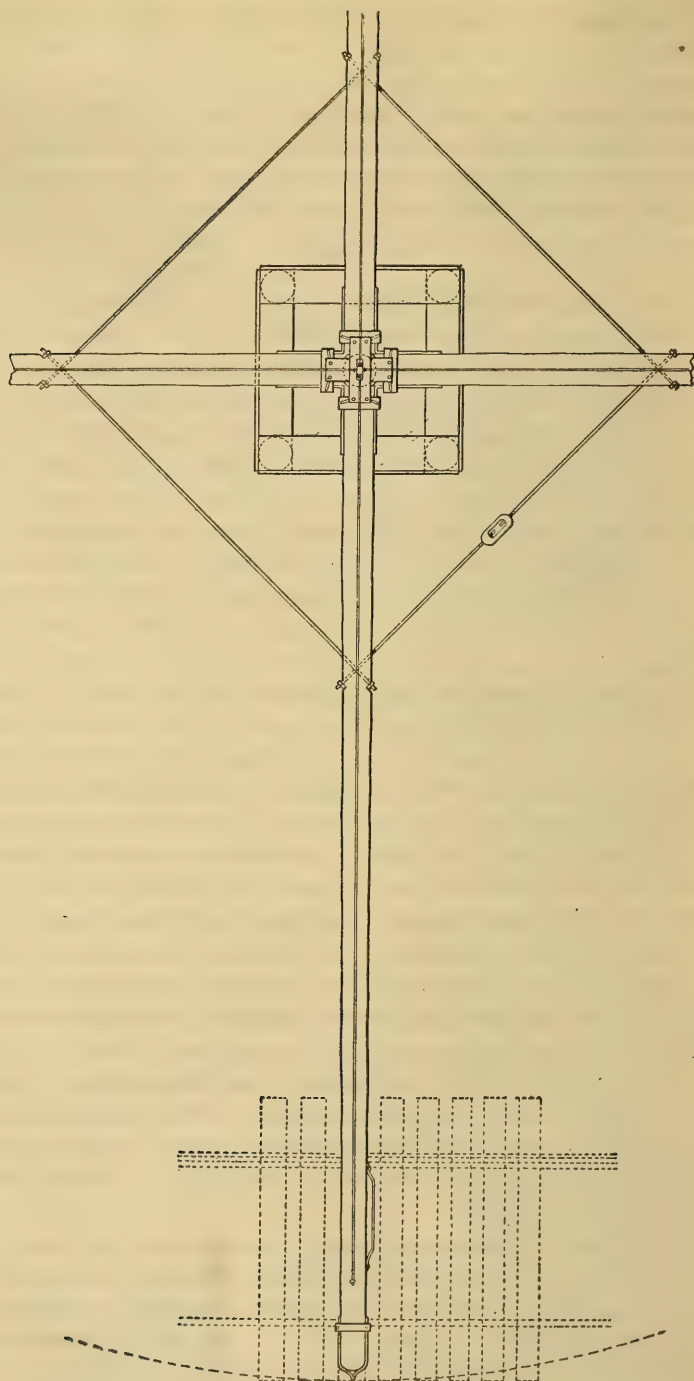


FIG. 77a.—An improved device for unloading logs. (Top plan view.)

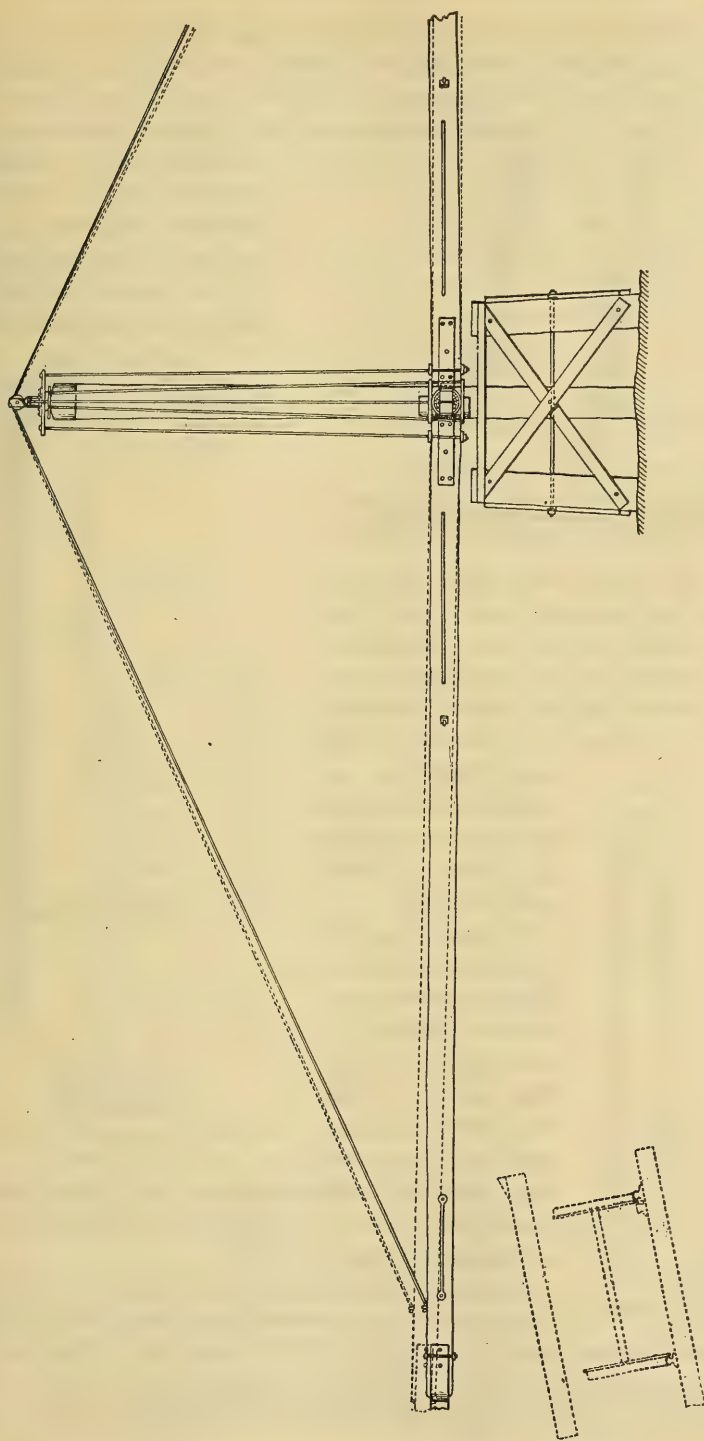


FIG. 77b.—An improved device for unloading logs. (Side view.)

the attachment of a collar with ball bearings. The rest of the shaft, or the part which is 10 inches in diameter, is set in a concrete base, high enough to allow the arms to clear the bunks, and far enough from the track to permit either arm when at right angles with the

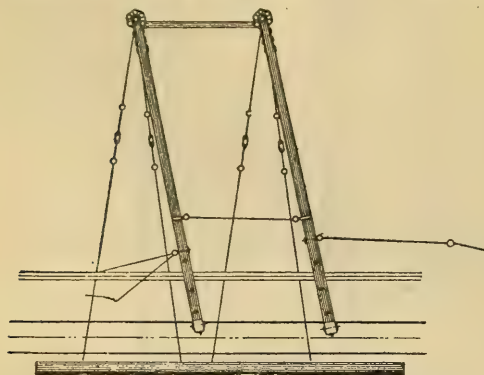


FIG. 78.—Ground plan of two-poke log unloader.

track to reach 1 foot beyond the outer rail. The concrete base is 9 feet square at the bottom and 6 feet square at the top. The repelling ends of both



FIG. 80.—Counterweight pile, two-poke log unloader.

arms are fitted with steel castings. These steel castings have sharp cutting edges, one of which engages a load of logs as the train moves toward the unloading device, penetrating the nearest log, thereby doing away with the necessity of attaching the arms to the car by a cable or some other method.

In unloading the train moves toward the unloader slowly, seldom finding it necessary to stop. The average time consumed in unloading 15 cars of logs, containing approximately 70,000 feet, is about 8 minutes, which includes the coupling of cars, knocking out the blocks, etc.

The cost of making and installing the machine described above amounted to \$1,000; \$900 for making and \$100 for installing. At the end of three years of use nothing had been spent for repairs. The cost of operation, other than train crew labor, consists of about one gallon of lubricating oil per year.

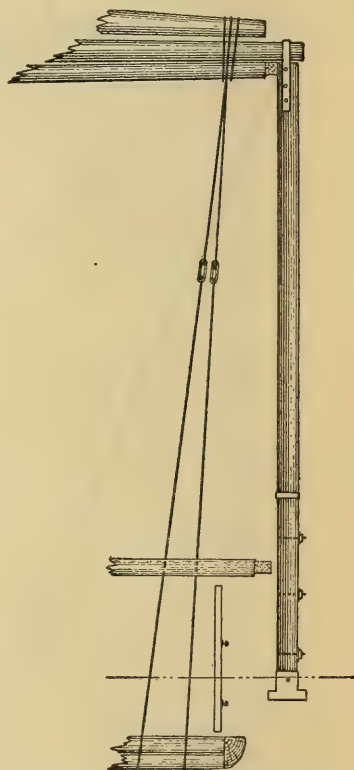


FIG. 79.—Cross section of two-poke log unloader.

(4) Figures 78, 79, and 80 show another type of two-poke log unloader. The two arms with this method, however, engage the load at the same time. Gravity is used to pull the arms into position to engage the load of logs. A line fastened to the arms leads through a block hung to a pile, thence through a block at the top of the pile. To the free end of this line a weight is attached. It is thought that the drawings are self-explanatory, making comments dealing with the construction and operation of the device unnecessary. The machine is said to unload one car of logs per minute under favorable conditions. In one case, with this device, cars were unloaded at the rate of one car every 3 minutes.

The total cost of making and installing this device depends on the location, ranging from \$700 to \$1,000. The bill of material is approximately as follows:

BILL OF MATERIAL.

Piles:

83 50-foot piles.

1 75-foot pile.

Caps:

66 linear feet 12 by 14 inch timbers.

24 linear feet 12 by 12 inch timbers.

2 pieces 6 by 12 inch by 14 feet.

1 60-foot log, 2 feet in diameter.

2 $\frac{3}{4}$ inch by 30 inch bolts.

3 $\frac{3}{4}$ inch by 16 inch bolts.

10 $\frac{3}{4}$ inch by 16 inch bolts.

10 $\frac{3}{4}$ inch by $\frac{5}{16}$ by 3 inch washers.

30 $\frac{3}{4}$ inch by 24 inch drift bolts.

240 square feet $\frac{1}{4}$ -inch sheet iron.

60 6-inch boat spikes.

Booms:

2 50-foot logs, 1 foot 6 inches in diameter.

2 unloader points.

2 $\frac{1}{4}$ inch by 6 inch by 12 feet sheet iron.

28 $\frac{3}{4}$ inch by 20 inch bolts.

32 $\frac{3}{4}$ inch by $\frac{5}{16}$ inch by 3 inch washers.

40 $\frac{7}{8}$ -inch cable clamps.

4 1 inch by 9 feet turnbuckles.

2 1 inch by 20 inch I bolts.

2 1 inch by 4 inch by $1\frac{1}{8}$ inch washers.

1 14-inch sheave wheel.

1 1 inch by 16 inch bolt.

1 $\frac{1}{4}$ inch by 3 inch by 18 inch sheet iron.

2 1 inch by 4 inch by $1\frac{1}{8}$ inch washers.

2 10-inch single sheave blocks.

1 20-foot $1\frac{1}{2}$ -inch log chain.

2 $\frac{1}{4}$ inch by 1 foot 6 inch diameter sleeves.

2 $\frac{1}{4}$ inch by 4 inch diameter rings.

PORTABLE ENGINE.

Where it is not practicable to dump all the logs at one spot, or where it is desirable to dump them at different points, it may be necessary to use a self-propelling unloader, which runs on an independent track along the main track. Moving from car to car, the machine unloads each car in rapid succession. To unload, the line is passed under the load and made fast to the brow skid. The friction drum is thrown in, tightening the line. This action raises the load free from the bunks, and at the same time pushes it off. This machine can also be used as a general utility car for building bridges, picking up stray logs along the track, building track, etc.

There are two types of portable unloaders. One has a stationary boom, a single drum, and reversible engines. The other has a live boom, which makes two drums necessary. A live boom increases the use of the machinery, since it makes it possible to reach out over the pond to break jams or pick up loads from barges. The engines of this type of unloader are not reversible, they are made to back by a change of gears. The machines have a capacity of about 20 tons and will run up an 8 per cent grade. The stationary boom machine is shown in figure 81.

The selling prices of these unloaders f. o. b. the factory are: Stationary-boom type, \$2,500; live-boom type, \$3,500. Since the use of this machine necessitates a second track, the cost of constructing a dump is greater when it is to be used with a portable log unloader than when some other method is to be used.

The work of unloading is generally done by the train crew, with the assistance of an unloading engineer. In some cases when the logs are delivered at the dump by a common carrier railway company the unloading is done by the booming and sorting crew. The work proceeds about as rapidly with this method as any other.

WATER TRANSPORTATION.

Water has been used to transport logs in every important lumbering region of the United States. It is still used extensively in the eastern part. In other regions it has to a great extent been superseded by railroads, because of the exhaustion of the timber supply near drivable streams, the extensive logging of nonfloatable species, and the increased value of stumpage.

Water transport never gained the foothold on the Pacific coast that it did in other lumbering regions, and it is now of minor importance, except where the logs are brought to the shores of the Columbia River, Puget Sound, Grays Harbor, Willapa Harbor, and other points on the Pacific Ocean, and then rafted and towed to the mills. The superiority of railroads over river driving was realized

by logging operators before the timber resources of the region under discussion were to any extent opened up. Furthermore, this region is not traversed by numerous streams suitable for the driving of the large timber that is characteristic of the region. Of course, logs are frequently dumped into relatively large rivers near their mouths and allowed to float singly for short distances to the sorting and rafting works.

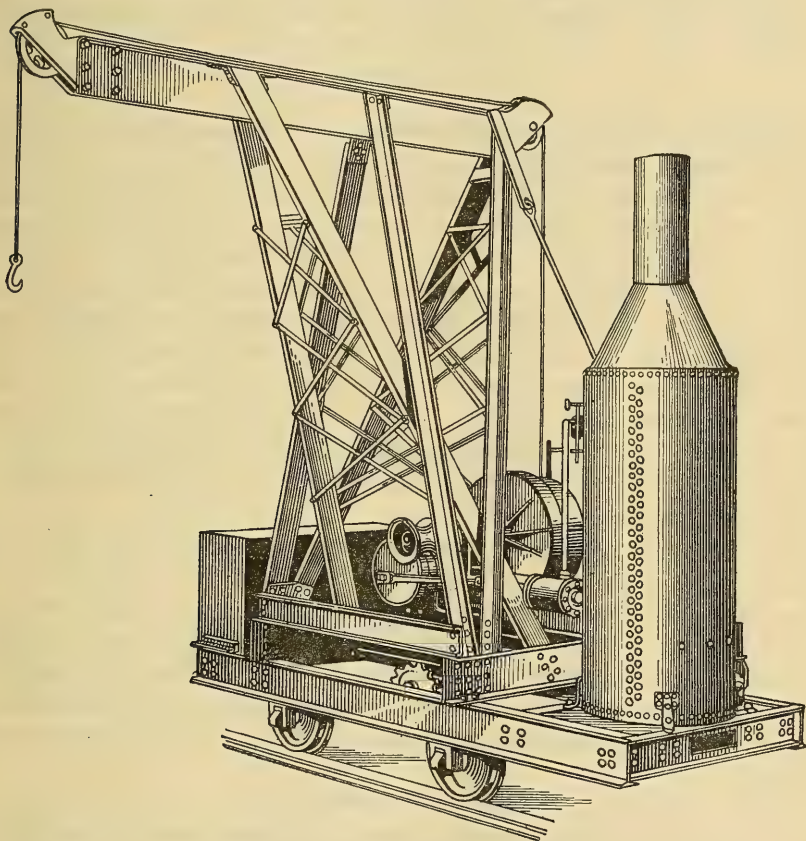


FIG. 81.—Stationary-boom unloader.

Flumes and sluices are used in different regions of the United States to transport sawlogs, shingle bolts, crossties, cordwood, pulpwood, mine timbers, and the like from the forest to the mills, drivable streams, or railroads. In the Douglas fir region, however, log flumes are not used. To the knowledge of the writer only one logging operator uses one. For this reason a discussion of log fluming has no place in this publication. Fluming is dealt with in Bulletin 87 of the Department of Agriculture, under the title of "Flumes and fluming."

DRIVING.

The driving of logs on rough water and small streams is practiced only to a limited extent in the Douglas fir region, and, excepting a few cases, only in the Grays Harbor and Willapa Harbor sections. Most of the timber so transported is driven on improved streams by separate driving companies at fixed rates per thousand feet, the driving of timber on unimproved streams being a very primitive method, which is resorted to only to a limited extent. Very little National Forest timber has been, or will be, driven in the form of sawlogs.

RATES.

The following are the driving rates on the Humptulips and Wishkah Rivers in Washington:

On the Humptulips River all logs 40 feet and under in length vary from \$0.30 to \$0.60 per thousand feet. The airline distance ranges from 14 to 34 miles. On logs 42 to 60 feet in length the rate is from 45 to 75 cents, and on logs over 60 feet in length the rate is from 65 to 95 cents. The cost of breaking out landings is borne by the logging operators. On the Wishkah River the rate for logs 40 feet and under in length ranges from 60 to 75 cents per thousand feet. The distance is from 15 to 28 miles. On logs 42 to 60 feet in length the rate is from 75 to 90 cents, and on logs over 60 feet in length from 95 cents to \$1.10 per 1,000 feet. A number of splash dams have been established on these rivers.

The driving companies assume charge of all the logs delivered afloat in the ponds of the dams or in the bed of the rivers below the dams, but, as has been pointed out, not in the landings. They operate their dams, and sluice, drive, and sack all logs in accordance with the driving act in the State law. The companies reserve the right to select the time when the streams shall be sacked, with the understanding that sacking will continue until all logs are delivered in the booms.

SORTING AND RAFTING.

It is the common practice of many logging operators to dump their logs into large streams or tidewater, so that the logs may be sorted, rafted, and towed to the mills. Two forms of rafts are employed. In a few cases in the Puget Sound region, the log output is dumped into rivers and made up into round, temporary rafts, the contents of such rafts being made into permanent rafts when they are delivered to tidewater. Practically all rafted logs, however, are made into permanent rafts at the unloading point.

SORTING.

In the early history of lumbering in the region, logs were bought and sold on the basis of "camp run;" that is, a logging operator

sold all the logs produced by his camp at an average price per thousand feet regardless of the percentage of the several species or the size and quality of the logs. At that time, when the selling price of the logs was low, or when the price of stumpage was low and the cost of logging considerably less than it is now, this method seems to have been satisfactory. As the price of logs advanced, the practice of selling on the basis of species and grades sprang up. Now the bulk of the log output of independent loggers is sold on this basis. Furthermore, independent loggers are giving considerable attention to the matter of further standardizing existing grades, also the question of the feasibility of increasing the number of grades. That there should be satisfactory standard grades for logs and that the grades should be as numerous as is practical can not be questioned. The loggers of British Columbia seem to have gone farther in the way of defining the log grades than those of the Columbia River and

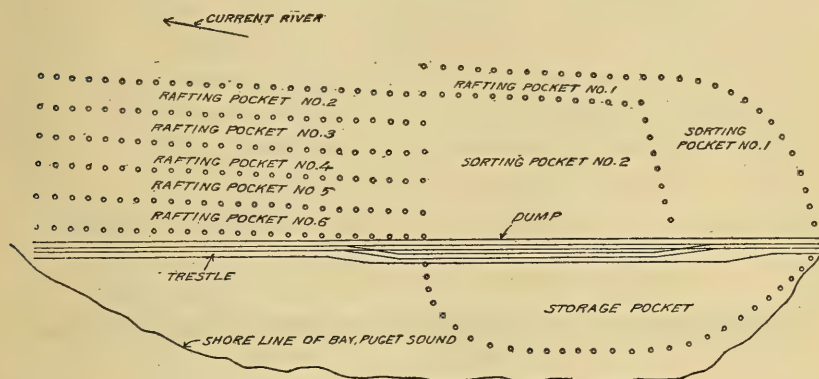


FIG. 82.—Booming and rafting works.

Puget Sound regions, and it would seem that the loggers could go still farther in any one of these three regions.

RAFTING.

Figures 82 and 83 show the sorting and rafting works in the case of two operations in the Puget Sound region. All works of this kind in this region are much the same, any differences, for the most part, being the result of differences in location and capacity. The main, or sorting, pocket, into which the logs are dumped, is a large area surrounded by logs chained end to end and held in place by piling. The rafting pockets, lanes leading off from the sorting pocket, are about 75 feet wide and from 800 to 1,000 feet long, and consist of parallel rows of piling, the piles being driven from 15 to 60 feet apart. Dolphins, consisting of three, four, or five piles driven in a cluster and bound together with a cable, are located at several points for mooring posts for tug boats and completed rafts. In addition to these im-

provements certain equipment, such as boom sticks, boom chains, peavies, axes, and pike poles, are required.

After the logs have been unloaded into the boom different species and grades are poled to different parts of the sorting pocket. This operation is not a distinct operation in the sense that all logs are sorted before rafting begins, since sorting and rafting may be considered as occurring at the same time. The rafters then string boom sticks across the far end and along both sides of the rafting pockets. Logs of approximately equal lengths are then poled or floated down the rafting pockets and stowed parallel to each other in the far end. Each row is known as a "tier," and two tiers usually constitute a "section." Manifestly all the logs in a section can not at all times run parallel with the outside boom sticks, some of them being placed

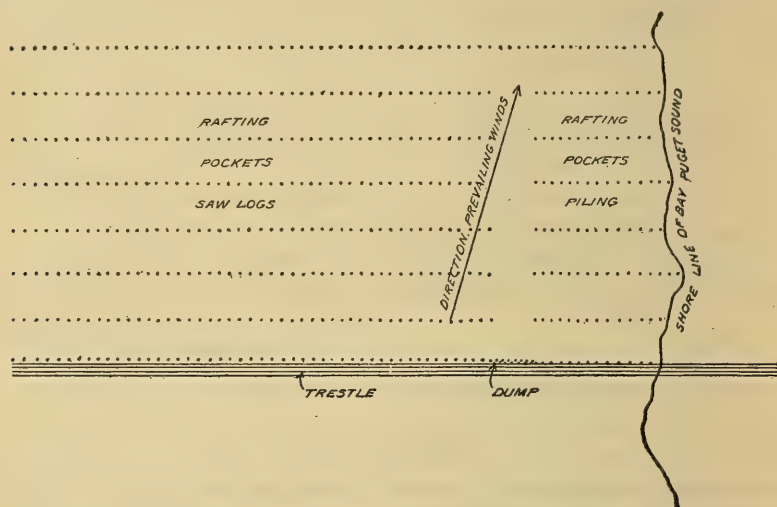


FIG. 83.—Booming and rafting works.

at right angles to these sticks. The main consideration is to place the logs so that the raft will be as compact as possible. As soon as a section is filled, a boom stick, called a swifter, is placed across the end at right angles to the outside boom sticks in order to keep the logs closely packed. New sections are then made up in the same manner, 10 to 14 sections constituting a raft. This applies to tide-water booms, where the work can be carried on only during a favorable tide. On large streams the procedure is practically the same.

The cost of a rafting and sorting works depends for the most part on the capacity, the method of sorting the logs, and the spacing of the piles. In the case of the works shown in figure 82, the cost amounted to \$1,000. The total number of piles driven was 250. The piling, which averaged about 32 feet in length, cost $6\frac{1}{2}$ cents per linear foot or \$2 per pile. The cost of driving was \$2 per pile.

In the case of the works shown in figure 83, the cost was about \$1,500, the piling costing \$4 per pile in place.

The maintenance of sorting and rafting works depends for the most part on the life of the piling. In the case of the \$1,000-works, the piling has a life of about 4 years; in the other case, 8 years. This means that the annual maintenance cost amounts to \$250 and \$188, respectively.

Outside boom sticks are from 75 to 82 feet in length; swifter sticks, from 66 to 70 feet. They are straight, sound, have a little taper, average about 16 inches at the small end, and have holes bored at each end for the insertion of boom chains. The average cost of an outside boom stick, with holes bored, is about \$11; the average cost of swifter sticks similarly prepared, \$7.50. Boom chains for outside sticks, made of 1-inch iron and weighing 80 pounds, cost about \$4.50 per chain. A swifter chain, made of a little lighter iron, costs about \$3.50. These chains are from 6 to 8 feet long and have a ring at one end, a toggle at the other. Standard light driving peavies are used in rafting. They cost about \$2 each. The pike poles, which average about 24 feet in length, cost about \$5 each. The total cost of boom sticks and chains for a complete raft is as follows:

31 outside boom sticks at \$10.....	\$310. 00
10 swifter sticks at \$7.50.....	75. 00
31 boom chains at \$4.50.....	139. 50
10 swifter chains at \$3.50.....	35. 00
Boring holes for 41 sticks.....	41. 00

Total.....	\$600. 00
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The life of boom sticks averages from two to three years. Boom chains have about the same life. Of course, in fresh water this equipment lasts much longer.

Sorting and rafting in the Columbia River and Puget Sound regions are ordinarily done by the logging operators with day labor. In a few cases it is done by separate companies at fixed rates per thousand feet. The rates in one case in the Puget Sound region are 35 cents per thousand feet for western red cedar and 25 cents per thousand feet for the other species. These rates include the unloading as well as the sorting and rafting of the logs. The logging companies furnish their own boom sticks.

In the Grays Harbor region logs driven or dumped into tidewater or the Chehalis River are generally rafted and sorted by separate companies at fixed rates per thousand feet. The sorting and rafting company operating at the mouth of the Humptulips River charges the following rates: For catching, sorting, rafting and delivering at the boom, 50 cents per thousand feet on logs or other timber products under 40 feet in length; 15 cents per thousand feet extra

for logs 42 to 60 feet in length; 35 cents per thousand feet extra for logs over 60 feet in length. The company reserves the right to base its charges on the mill scale or its own scale at the boom. Upon receipt of logs in the boom the company proceeds to raft them without unreasonable delay. As soon as a raft is ready for delivery and in absence of instructions from the owners as to its disposition, the company reserves the right, after giving five days' notice, to store the logs and to charge 10 cents per thousand feet for each thirty days or any fraction thereof. When logs are stored an additional charge of 25 cents per thousand feet is made for rafting and delivering the logs to the storage grounds. The company operating at the mouth of the Wishkah River charges the following rates: For catching, sorting, and delivering at its boom in suitable sticks furnished by the owners of the logs, 40 cents per thousand feet for all logs and other timber products under 40 feet in length; 15 cents per thousand feet extra for logs 42 to 60 feet in length; 35 cents per thousand feet extra for logs over 60 feet in length. The storage charge is 25 cents per thousand feet for the first month and 10 cents per thousand feet for each additional month. This charge includes the cost of delivering the logs to storage.

Logging operators frequently contract the sorting and rafting. In one case the operator paid the contractor \$1 per car for unloading, sorting, and rafting. This is at the rate of about 13 cents per thousand feet. The contractor only furnishes the operating labor, the dump and booming grounds being kept in repair by the logging operator.

The labor cost of sorting and rafting, where it is done by logging operators, ranges from 6 to 17 cents per thousand feet of output. In the case of 18 operations in the Puget Sound region the following range of labor costs was found:

Number of camps.	Labor cost per thousand feet.
	<i>Cents.</i>
3.....	6 to 8
7.....	9 to 10
6.....	13 to 15
2.....	16 to 17

In the case of 8 operations in the Columbia River region the following range of labor costs was found:

Number of camps.	Labor cost per thousand feet.
	<i>Cents.</i>
6.....	8 to 10
2.....	12 to 14

The variation in the labor cost of sorting and rafting is due to differences in the conditions under which the men work, or the average volume of timber sorted and rafted per man. In the case of a tidewater operation, a crew of seven men, working under favorable conditions, sorted and rafted 500,000 feet per day. The crew and wages were as follows:

Foreman -----	\$125. 00 per month.
Boom man -----	3. 50 per day.
4 rafters ----- (each) --	3. 00 per day.

Under adverse conditions when the wind is blowing in the wrong direction this crew will do less. In running water where the current carries the logs down the rafting pockets, a crew of four men may average as much as 500,000 feet per day. As a rule, each member of the crew, including the foreman, will average from 40,000 to 60,000 feet per day.

TOWING.

In the Columbia River and Puget Sound regions the cost of towing the logs from the booms to the mills, as a rule, is borne by the manufacturers, while in the Grays Harbor and Willapa Bay regions this cost, as a rule, is borne by the independent loggers. The operation is performed by separate companies at fixed rates per thousand feet. The rates charged in the Columbia River, Puget Sound, and Grays Harbor regions are as follows:

TABLE 33.—Rates for towing logs on Puget Sound, 1915.

	Anacortes.	Apple Tree Cove.	Ballard.	Blanchard.	Brown's Bay.	Port Susan.	Priest Point.	Mukilteo and Everett.	Seattle.	Blakely.	Tacoma.	Seabeck, Tarbo, and Brinnon.	Shelton.	Utsalady.	Bellingham.	Cherry Point.	Blaine.	Gamble.	Hadlock.	Union City and Pottatch.	Henderson Bay and Olympia.
Apple Tree Cove.....	\$0.50																				
Ballard.....	.50	\$0.25																			
Blanchard.....	.25	.60	\$0.60																		
Port Susan.....	.45		.35	\$0.50																	
Priest Point.....	.45		.25	.50	\$0.20	\$0.25															
Everett.....	.45		.25	.50	.20		\$0.15														
Seattle.....	.50	.25	.15	.60	.20	.35	.30	\$0.25													
Blakely.....	.50	.25	.20	.55	.20	.35	.30	\$0.15													
Tacoma.....	.60	.35	.30	.70	.35	.45	.40	.25	\$0.25												
Seabeck, Brinnon, and Tarbo.....	.60			.65			.40	.40	.40	.40	\$0.50										
Shelton.....	.30	.40	.40	.70		.50	.45	.45	.35	.30	.25	\$0.70									
Bellingham.....	.25	.60	.60	.20	.50	.70	.70	.30	.40	.40	.45	.45	\$0.55								
Blaine.....	.45	.70	.70	.45	.70	.70	.70	.70	.75	.75	.65	.65	.75	\$0.40							
Gamble.....	.50	.30	.35	.55	.25	.40	.30	.30	.35	.35	.45	.25	.45	.55							
Hadlock.....	.60	.35	.40	.60	.40	.45	.40	.40	.40	.40	.50	.40	.45	.40							
Olympia.....	.65	.45	.45	.70	.50	.60	.45	.45	.45	.45	.60	.25	.50	.50							
Discovery Bay.....	1.50			1.60		.55	.45	.45	.35	.30	.25	.70	.15	.55	1.60						
Brown's Bay.....	2.75	.50	.55	2.75		.55	.55	.55	.55	.55	.70	.60	.75	.65	2.75						
	.50		.20	.50				.20	.20	.20	.33				.50						

1 outside.

2 inside.

The cost of towing less than 300,000 feet is the same as for 300,000 feet. One to four sections may be towed at day rates. Demurrage is charged in all cases where the tug boat is delayed through the tow not being ready when the tug boat arrives at the boom. All tows are transported at the owner's risk.

TABLE 34.—Rates for towing boom sticks on Puget Sound, 1915.

	Anacortes.	Apple Tree Cove.	Ballard.	Blanchard.	Port Susan.	Priest Point.	Mukilteo and Everett.	Seattle.	Blakely.	Tacoma.	Seabeck, Brimmon, and Bellingham.	Shelton.	Utsalady.	Bellingham.	Cherry Point.	Blaine.	Gamble.	Hadlock.	Union City and Potlatch.	Henderson Bay and Olympia.
Apple Tree Cove.....	\$1.00																			
Ballard.....	1.00	\$0.50																		
Blanchard.....	1.00	1.00	\$1.00																	
Port Susan.....	1.00	.75	.75																	
Priest Point.....	1.00	.50	1.00	\$1.00																
Everett.....	1.00	.50	.75	1.00	\$0.50															
Seattle.....	1.00	.50	.50	1.00	.75															
Blakely.....	1.00	.50	.50	1.00	.75		\$0.50													
Tacoma.....	1.25	.75	.75	1.50	1.00	1.00	1.00	\$0.50	\$0.50											
Seabeck, Brimmon, and Tarboo.	1.25	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	\$1.25										
Shelton.....	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	.75	\$1.25									
Utsalady.....	.75	.75	.75	.75	.75	.50	.50	.75	.75	1.00	1.00	\$1.25								
Bellingham.....	.50	1.25	1.25	.60	1.00	1.00	1.00	1.25	1.25	1.50	1.75	1.75	1.25	\$1.00						
Blaine.....	1.00	1.50	1.50	1.00	1.50	1.50	1.50	1.50	1.50	1.75	1.75	1.00	1.00	1.00	\$0.50					
Gamble.....	1.25	.75	.75	.60	.75	.75	.75	.75	.75	1.00	.50	1.00	1.00	1.00	1.50	\$1.50	\$0.75			
Hadlock.....	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	.75	1.00	1.00	1.00	1.00	1.75	1.00	\$1.00		
Potlatch.....	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	1.25	.50	1.50	1.25	1.50	1.50	1.75	1.00	1.00	1.00	
Olympia.....	1.50	1.00	1.00	1.50	1.00	1.00	1.00	1.00	1.00	.60	1.25	.50	1.25	1.25	1.25	1.75	1.00	.75	1.25	\$1.50
Discovery Bay.....	1.00	1.00	1.00	1.25	1.00	1.00	1.00	1.00	1.00	1.25	1.00	1.00	1.25	1.25	1.00	1.50	.75	1.00	1.00	
Brown's Bay.....	1.00		.50	1.00	.50	.50	.50	.50	.50	1.00	1.00	1.00	.75	1.00		1.50	.75	1.00	1.00	

TABLE 35.—*Rates for towing Douglas fir logs on the Columbia River, 1915.*

Destination.	Upper Cape Horn.	Wahougal.	Lake River.	Wal-ers Island and intermediate points.	Cool Creek, Lower Cape Horn.	Beaver, Westport, Clifton, Eloqueman.	Between Clifton and Tongue Point.	Between Eloqueman and Harrington Point.	Grays Bay and Deep River.	Grays River and Youngs Bay.	Vancouver, Chapman.	Knappa, Stella.	Goble.
Portland.....	\$0.50	\$0.50	\$0.50	\$0.50	\$0.55	\$0.60	\$0.65	\$0.65	\$0.85	\$0.90	.....	.....	.....
Vancouver.....	.....	.....	.50	.50	.55	.60	.65	.65	.85	.90	.....	.....	.....
St. Helens.....	.....	.....	.....	.....	.....	.45	.50	.50	.70	.75	.....	.....	.....
Kalama.....	.60	.55	.25	.....	.....	.....	.....	.....	.....	.....	\$0.25	.....	.....
Rainier.....	.60	.55	.25	.....	.....	.....	.....	.....	.....	.....	.25	.....	.....
Prescott.....	.60	.55	.25	.....	.....	.....	.....	.....	.....	.....	.25	.....	.....
Westport.....	.70	.60	.35	.....	.....	.....	.....	.....	.....	.75	.35	\$0.20	\$0.25

NOTE.—These rates apply to tows of 200,000 feet or more. Tows of less volume are considered as containing 200,000 feet.

The rates for towing cedar, cottonwood, and hemlock on the Columbia River are 10 cents higher than the rates on Douglas fir logs. When cedar, cottonwood, or hemlock tows contain less than 200,000 feet the rates applying to Douglas fir tows are increased as follows:

- Less than 50,000 feet, 50 cents extra.
- From 50,000 to 100,000 feet, 40 cents extra.
- From 100,000 to 150,000 feet, 35 cents extra.
- From 150,000 to 200,000 feet, 25 cents extra.

The rate for returning boom sticks from Portland to Grays Harbor and Youngs Bay is 75 cents per stick; from all other points, 50 cents.

On Grays Harbor the towage rates from the booms to the mills at Hoquiam, Aberdeen, and Cosmopolis, including the use of the sticks for rafts, range from 10 to 30 cents per thousand feet. For example, the rate from the boom at the mouth of the Humptulips River to Hoquiam and Aberdeen is 25 cents per thousand feet, and from the same point to Cosmopolis it is 30 cents per thousand feet. From the boom at the mouth of the Wishkah River to the nearest mills the rate is 10 cents per thousand feet, and from the same point to the most distant mills at Hoquiam the rate is 20 cents.

Starting with 1894, several rafts of logs have been towed each year from the Columbia River to southern California. These ocean-going rafts contain from 4,000,000 to 5,000,000 feet of timber, or approximately 10,000 piles. They are built cigar-shaped, generally about 900 feet long and from 50 to 60 feet wide, and draw about 24 feet of water, with 12 feet above the surface.

GENERAL EXPENSES.

Operators find "General expenses" a convenient term to designate costs which are not related to any distinct step in the logging opera-

tion, such as supervision of the operation as a whole, office expenses, taxes, selling costs, and miscellaneous items like cruising and fire protection. This classification has not been standardized, and different items of expense are included in it.

General expenses are the most easily overlooked of any in making a timber appraisal. Their inclusion in the calculation is as important, however, as the cost of felling and bucking. The principal general expense charge is general superintendence.

WOODS SUPERVISION.

Many operators include in woods supervision all the supervision of the logging operation from the woods to the raft or mill, also certain general expenses around the camp, such as the pay of the bookkeeper, timekeeper, scaler, logging engineer, night watchman, etc. Other operators prorate such expenses against the major departments of the logging operation. As a rule the salary of the logging superintendent or manager does not appear under this heading. The salaries of the foreman, bookkeeper, timekeeper, etc., are given under the heading "Logging in general."

FIXED CHARGES.

SUPERINTENDENCE.

In the main the industry is not burdened with a superabundance of general salaried help; and low salaries for managers and logging superintendents, considering the character of the work and the capital invested, are the rule.

The cost of superintendence per thousand feet varies from 7 to 20 cents. The cost of superintendence and commissions in the case of twenty camps in the Puget Sound region and ten camps in the Columbia River region is as follows, commissions including the amounts paid by some of the operators to an association or individual for selling the logs:

Number of camps.	Cost per thousand feet.
Puget Sound region:	Cents.
7.....	7 to 10
6.....	11 to 15
7.....	16 to 20
Columbia River region:	
4.....	8 to 10
3.....	11 to 15
3.....	16 to 20

The camp of one independent logging operation running four sides is in charge of a foreman who receives \$200 per month. The general superintendence of the whole operation, including the dis-

posal of the log output, is in the hands of a manager who receives \$5,000 per year. The manager spends from one-fourth to one-third of his time in the woods. The salary of the camp foreman is charged directly to the cost of running the camp; that of the manager, to general expense. No officer of the company other than the manager receives a salary. The help at the head office, other than the manager, consists of a bookkeeper and office boy.

In the case of another independent logging operation running four sides, the camp is directly in charge of a foreman who receives \$175 per month. This foreman has an assistant who receives \$125 per month. A logging superintendent, who spends practically all his time in camp, has general charge of the operation, the disposal of the logs, and the purchase of equipment and supplies. The camp office is practically the only office this company has, since all paper work is performed in the camp. This operation has a general manager, who, having a number of interests, does not give much attention to the affairs of the company. His salary is \$1,000 per year. The salaries of the superintendent, foreman, assistant foreman, and bookkeeper are charged as camp expense.

In the case of another independent logging operation there is no general expense as far as general superintendence is concerned. A logging superintendent, who spends practically all of his time in camp, directs the operation. He is assisted by a felling and bucking foreman, a logging foreman, and a railroad foreman. These three men are directly responsible to the superintendent. The felling and bucking foreman directs the felling and bucking department; the logging foreman, the yarding and loading departments; and the railroad foreman, the construction and maintenance of the railroad. The superintendent has direct charge of the operation of the train. The superintendent receives \$4,000 per year; the felling and bucking foreman, \$125 per month; the logging foreman, \$150 per month; and the railroad foreman, \$125 per month. The salaries of the manager and foremen, as well as the salaries of the bookkeeper and scaler, are charged under the heading "Camp Expense." The company has no office other than that in the woods, and pays no salaries other than those mentioned.

In the case of an operation that both logs and manufactures, the logging camp is directly in charge of a camp foreman. This operation has an output of about 125,000 feet per day. A manager, who has general supervision of both the logging and manufacturing operations, receives \$5,000 per year, one-half of which is charged against the logging.

GENERAL OFFICE EXPENSE.

General office expense may include clerical help, rent of office quarters, association dues, and the like. One bookkeeper, who is a stenog-

rapher, with possibly an office boy, should be ample help of this character for the largest independent logging operations.

TAXES.

Taxes on standing timber are frequently considered as an operating cost. Many operators, however, consider the tax on their timber as one of the costs of carrying stumpage. In connection with national forest timber appraisals this factor does not enter. Equipment and improvements are subject to taxation, regardless of where they are used or made, and so appraisals should always provide for taxes of this character. The system of taxation, also the rates, are discussed briefly in the section headed "Logging in General."

MISCELLANEOUS COSTS.

There are certain costs which may be grouped with or apart from general expenses; others should properly be so classed. The cost of workmen's compensation acts falls into the former class; the cost of fire protection, into the latter. Except as fire protection is maintained to protect woods equipment and improvements, it seems to be a charge for carrying stumpage rather than a logging cost. A considerable proportion of the fire fighting done by operators is, however, for the purpose of protecting equipment, improvements, and the like. Forest service timber sale contracts require each purchaser to use his employees in fighting fires on certain defined areas. The cost of this work may be properly included in the appraisal as a logging cost.

EXTRA COST OF LOGGING UNDER FOREST SERVICE REGULATIONS.

The preceding discussion of logging methods and costs, unless otherwise noted, is based on what is happening on private timbered areas. However, since the utilization of Douglas-fir stands within the National Forests is practically the same as that of similar stands on private lands, it applies for the most part to operations upon National Forests. There is this difference: Logging upon the National Forests is conducted under contracts with the Government, which provide certain regulations relative to cutting, utilization, logging, and fire protection. Compliance with these contracts ordinarily involves a little extra labor and thus adds to the cost of logging. For example, Forest Service timber-sale contracts dealing with Douglas-fir stands provide for the leaving of seed trees, from the base of which brush and other inflammable material is removed; the building of fire lines around certain areas, the felling of snags, the burning of slashings, the cutting of lower stumps, the utilization of more of the tops of the trees, and the logging of a higher percentage of the defective material than is ordinarily prac-

ticed in cutting private stumpage. The cost of this extra work varies from 8 to 15 cents per thousand feet.

TOTAL COST OF LOGGING AT ONE OPERATION.

The following deals with the cost of logging at a rather large operation in the Pacific Northwest during 1910, 1911, 1912, and 1913. Unless otherwise noted the discussion following the tables applies to 1912. It is impossible to discuss all the costs given. For the most part, the classifications are those of the operator.

CHARACTER OF COUNTRY.

Part of the area logged during 1912 is shown in figure 20. The country is mountainous, rough, and badly broken. The slopes in general are steep. No rock outcrops or cliffs were encountered. The streams are not of drivable size, but are so located as to make it unnecessary to pump water for long distances.

SOIL.

The soil is sandy loam with a clay subsoil. It drains poorly, making it necessary to gravel-ballast all spur railroads used for a year, also those used during the wet season. Practically all the ballast was hauled 3 miles.

OUTPUT.

The output for 1912 was as follows:

Species.	Scale.	Number of logs.	Contents of average log.
	<i>Feet b. m.</i>		<i>Feet b. m.</i>
Douglas fir.....	32, 204, 222	14, 369	2, 241
Spruce.....	829, 157	494	1, 667
Cedar.....	2, 868, 684	2, 665	1, 076
Hemlock.....	1, 886, 065	2, 301	819
Total.....	37, 788, 128	19, 829	.....

Number of machine days.....	531
Average scale per operating day, feet b. m.....	151, 797
Average scale per yarding engine per yarding day, feet b. m.....	71, 164
Average number of logs per yarding engine per yarding day.....	37
Average scale per log, feet b. m.....	1, 904
Number of cars loaded.....	5,099
Average scale per car.....	7, 410

Total cost of logging.

LABOR.

[Output, feet board measure. Cost per 1,000 feet.]

Items.	1910	1911	1912	1913
	16,722,000	26,605,000	37,788,000	41,870,000
1. Felling.....	\$1.104	\$0.313	\$0.168	\$0.230
2. Bucking.....		.457	.382	.390
3. Yarding.....	1.995	1.124	.746	.503
4. Roading and swinging.....				.040
5. Moving logging engines.....			.044	.080
6. Landing construction.....			.030	.090
7. Woods water system.....				.056
8. Pole-road construction.....		.046	.016	.016
9. Loading.....		.152	.112	.147
10. Spur railroad construction.....	.528	.313	.296	.467
11. Railroad maintenance.....	.346	.154	.189	.300
12. Railroad operation.....	.459	.152	.190	.180
13. Unloading.....	.110	.015		.009
14. Maintenance, locomotives and cars.....	.261	.187	.155	.100
15. Maintenance of logging engines and other equipment.....			.077	.126
16. Breakwater.....	.105	.013		
17. Moving camp.....	.006	.006		.019
18. Office.....				.036
19. Camp management.....	.327	2.15		
20. Miscellaneous.....			.031	
Total.....	5.241	3.147	2.436	2.789

SUPPLIES, REPAIR PARTS AND MATERIALS, AND REPLACEMENT OF SMALL EQUIPMENT.

1. Wire rope.....	\$0.495	\$0.403	\$0.180	\$0.214
2. Rigging.....			.064	.045
3. Blocks and hooks.....			.021	.018
4. Fuel oil and supplies.....	.120	.066	.202	.256
5. Fuel wood, locomotives.....	.069	.028		
6. Oil and grease.....	.040	.030	.027	.043
7. Waste and packing.....			.006	
8. Powder.....			.048	.055
9. Shop supplies.....	.146	.088	.030	.051
10. Shop tools.....	.076	.045	.001	.027
11. Track and grading tools.....			.012	
12. Miscellaneous tools.....			.001	
13. Felling and bucking tools.....			.018	
14. Woods water system, supplies.....	.017	.011	.005	.016
15. Ties.....	.052	.040	.050	.027
16. Miscellaneous supplies.....	.030	.021	.023	.040
17. Freight.....	.150	.080	.102	
Total.....	1.195	.812	.790	.792

CAMP EXPENSES.

1. Rental right-of-way.....	\$0.108	\$0.069	\$0.046	\$0.022
2. Sorting and rafting (contract work).....	.450	.450	.450	.450
3. Charity.....				.002
4. General.....	.053	.033		.003
5. Telephone.....	.002		.005	
6. Boiler inspection, fire and liability insurance.....	.105	.064	.045	.030
Total.....	.718	.636	.546	.527

DEPRECIATION.

1. Main-line railroad grade.....	\$0.149	\$0.096		
2. Track equipment.....			\$0.038	\$0.076
3. Logging engines.....	.101	.090	.041	.072
4. Locomotives.....			.059	.050
5. Rolling stock.....	.106	.060	.023	.038
6. Buildings and equipment.....			.012	.015
Total.....	.356	.246	.173	.251

GENERAL EXPENSE.

1. General management.....	\$0.012	\$0.092	\$0.070	\$0.081
2. Taxes.....	.072	.045	.040	.037
Total.....	.084	.137	.110	.118
Grand total.....	7.594	4.978	4.055	4.477

DISCUSSION OF LOGGING COSTS.

LABOR.

The cost of felling and bucking (1 and 2) in 1912 and 1913 includes the wages of the fallers, buckers, head buckers, and the assistant to the head buckers, also a portion of the camp supervision. In 1910 and 1911, an assistant to the head buckers was not employed, and the cost of camp supervision was classified under a separate heading.

The head buckers has charge of the felling and bucking, and, with the aid of an assistant, marks the trees into log lengths. The timber is large and the country rough, making the work of bucking hazardous. It is difficult to get the buckers to cut the logs the proper length, and the assistant to the head buckers has been found profitable. The log lengths are measured with a tape.

In 1912 the shortest logs cut were 16 feet long, but there were few cut shorter than 24 feet. A few 60-foot logs were cut, and a large number of 40-foot logs. The logs averaged about 32 feet in length.

During 1912 the operation averaged a little more than 3 sets of fallers and a little more than 16 buckers. In March there were 10 fallers and 16 buckers.

The wages paid in 1912 were as follows:

Head fallers	-----per day--	\$3. 75
Second fallers	-----do-----	\$3. 40- 3. 50
Buckers	-----do-----	3. 25
Head buckers	-----do-----	3. 75
Assistant to head buckers	-----do-----	3. 00

It is the policy of the logging superintendent to bring the logging spurs close to the timber, so that it can be single-hauled (3 and 4) from the stump to the landing, unless the cost of constructing the spurs is excessively high or the operation of trains on them is impractical. Of course, other factors would influence him in deciding whether it was impractical to build a spur line to open up a body of timber. Figure 20 shows that much of the timber logged in 1912 was double hauled. This timber, as in the case of 1913, was hauled over the ground. The amount of double hauling done in 1913 is suggested by the labor cost, which appears as a separate item.

At the beginning of the year 1911 no timber was opened up except two small tracts, one of which had to be roaded and yarded a maximum distance of 7,500 feet; the other, a maximum distance of 4,000 feet. In both cases the timber had to be moved downhill. Later in the year other tracts were opened with pole roads and chutes, this timber being transported 5,000 feet at times. Fully 60 per cent of it was double hauled.

In 1912 and 1913 all the scalers' wages and a part of the camp supervision were charged against the cost of yarding and swinging. The following yarding crew was used in 1912:

Hooktender	-----per day--	\$5. 00-\$6. 00
Head rigger	-----do----	3. 75- 4. 25
3 riggers	-----do----	3. 00- 3. 50
Sniper	-----do----	3. 00- 3. 25
Chaser	-----do----	3. 00- 3. 25
Signalman	-----do----	2. 50

At times it was deemed necessary to use four riggers besides the head rigger, also an extra chaser.

When double hauling was in progress, it was necessary to use the following additional men: Engineer, \$3.50 per day; 1 or 2 chasers, \$3.00 to \$3.25 per day.

The above crews were employed when oil was used as fuel in the logging engines.

Moving logging engines (5) includes the cost of moving all logging engines, such as yarding, swinging, roading, loading, and power-scraping engines, from one site to another.

Landing construction (6) includes the cost of building eight landings. The cost includes clearing of site, constructing landings, digging engine settings, raising gin poles, and putting rigging on gin poles.

Woods water system (7) includes the cost of the laying of pipe lines and the pumping of the water for logging engines.

For loading the logs (9) in 1912 a gin pole, crotch line and grabs, and a double-drum loading engine were used. The loading crew during the major part of this year consisted of the following:

Engineer	-----per day--	\$3. 25
Fireman	-----do----	2. 75
Head loader	-----do----	3. 75
Second loader	-----do----	\$3. 25- 3. 50

Firemen cut the wood for the loading engines, also started the fires in the roading or yarding engines, which burned oil. One-half of the fireman's wages was charged against the loading, the other half against the yarding. At times only one loader was charged against the loading, the chaser with the yarding crew doing the work ordinarily done by a second loader.

Spur railroad construction (10) includes the cost of clearing right of way, grading, laying the track, and ballasting the track with gravel. It is not possible to give the total length of spurs built in 1912. Three pieces of spur track, amounting to 6,800 feet, were built for \$5,448, which is at the rate of \$4,225 per mile.

Railroad maintenance (11) includes the cost of keeping all railroads in good condition as to surface and alignment, repairing trestles, keeping ditches open, taking care of slides, and digging and hauling gravel after the roads had been put in operation. In 1912 it includes the upkeep of about 6 miles of track. During this year section foremen were paid \$3.50 per day; section hands, \$2.50 per day.

Up to May 1, 1916, three locomotives (12) were used, two of which were geared 28 and 42 ton locomotives, and one a 22-ton direct-connected engine. During the remainder of the year another 42-ton geared engine was added, and the 22-ton direct-connected engine discarded. In 1912 the haul from the landings to the dump averaged about 6 miles. The conductor and brakeman, together with a man regularly employed at the dump, dumped the logs. The train crews in 1913 were as follows:

42-ton:

Engineer	-----per day--	\$5.00
Conductor	-----do----	4.25
Brakeman	-----do----	3.75

33-ton:

Engineer	-----do----	4.50
Conductor	-----do----	4.75
Brakeman	-----do----	3.75

The locomotives burned oil.

Maintenance of locomotives, cars, logging engines, and other equipment (14 and 15). During 1912 20 flat cars and 6 sets of trucks were used. It is impossible to give the logging-engine days in logging, chunking-out, grading, landing, construction, gravel digging, loading, pile-driving, etc. The following machines were used during some part of the year: Four 10 by 13 inch; two 11 by 13 inch; one 9½ by 11 inch; one 9 by 10 inch; one 8½ by 10 inch; one 7 by 9 inch.

Three sides were operated until April 1; after that date two. Double hauling was done at different times during the year.

The regular shop crew was as follows:

Blacksmith	-----per day--	\$5.00
Blacksmith helper	-----do----	3.50
Machinist	-----do----	5.25
Machinist helper	-----do----	3.25
Car tinkerer	-----do----	3.25
Carpenter	-----do----	3.50
Second carpenter	-----do----	3.00
Rigging man	-----do----	3.40

Camp management (19) includes the cost of camp foreman, time-keeper, bookkeeper, etc. During 1912 and 1913 this cost was pro-rated against the major department of the operation.

Wire rope cost includes the cost of the main hauling, trip, and main loading lines.

Rigging cost includes the cost of chokers, tag lines, crotch lines, straps, etc.

Powder cost includes the cost of the powder used both in yarding and railroad construction.

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APPLE POWDERY MILDEW AND ITS CONTROL IN THE ARID REGIONS OF THE PACIFIC NORTHWEST.¹

By D. F. FISHER,

Assistant Pathologist, Fruit-Disease Investigations.

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ECONOMIC IMPORTANCE OF POWDERY MILDEW.

Apple powdery mildew is usually considered as of only minor importance and principally affecting nursery stock in the eastern part of the United States, only becoming serious in restricted localities. Occasionally it is severe in Utah, Colorado, New Mexico, and the East on old trees, but in the apple-growing districts of the Pacific coast the conditions are such that it often becomes serious. The arid climate of the hot interior valleys of the Pacific Northwest has proved an effective safeguard against fungous diseases in general, but apple powdery mildew is endemic.

In these regions, where deciduous-fruit growing, and especially apple growing, has become such an important industry, orcharding is generally carried on under very intensive conditions and the in-

¹ Acknowledgment is due Dr. Charles Brooks, of the Office of Fruit-Disease Investigations, Bureau of Plant Industry, for many helpful suggestions during the course of the work, and to Messrs. E. J. Newcomer, of the Bureau of Entomology, and M. M. Brown and L. C. Carey, formerly assistants in spraying experiments, who actively assisted in the field work.

dustry is highly specialized. In the Wenatchee Valley, Washington, where the experimental work herein reported was carried on, the arable land is almost entirely taken up with apple orchards; and, having a high valuation, it is cut up into small holdings, the average orchard area being somewhat less than 10 acres for each owner. Great attention is given to every detail of the orchard operations; pests and diseases are vigorously combated, and every effort is made to produce a maximum amount of the perfect high-colored fruit which has made this region notable. Imperfections and markings affecting only the appearance of the apples cause a loss of grade and consequent financial loss to the grower. If, as in the case of apple powdery mildew, there is added to this effect a lessened production, every effort to remove the cause is justified.

The seriousness of apple powdery mildew is greatly modified by the character of the season in any given year. The spread of infection is greatly facilitated by a rainy spring. During seasons when conditions for spore germination are most favorable the disease assumes epidemic proportions and is the cause of serious loss. It not only attacks the foliage and tender wood growth, but also destroys fruit buds and directly attacks the fruit. In the Wenatchee Valley the russetting of the fruit is considered one of the most serious effects of the disease.

REVIEW OF THE LITERATURE.

The first mention of the disease in this country was made by Bessey (1)¹ in 1877. He reported a serious outbreak of powdery mildew (*Podosphaera kunzei*) on seedling apples and cherries in the college nursery in 1871.

The fungus was first described as *Sphaerotheca leucotricha* by Ellis and Everhart (2) in 1888.

Galloway (3) carried on the first extensive experimental work and published the first recommendations for control. In 1889 he reported that the disease occurred abundantly through all the region east of the Mississippi. He found that it was confined to attacks on young trees in the nursery, especially seedlings, the leaves becoming dry and brittle and of so little use that the trees were rendered worthless for budding. He stated that the disease is spread by wind dissemination of spores, aided by insects, rain, and other agents. He pointed out that the ascospores are of no practical importance and that the fungus winters over in mycelial form. In a later publication (4) he reported the successful use of ammoniacal copper-carbonate spray in controlling the disease.

¹ The serial numbers in parentheses refer to "Literature cited" at the end of this bulletin.

Burrill (5) in 1892 changed the name of the fungus to *Sphaerotheca mali* (Duby), identifying it with *Erysiphæ mali* of that author, but this fungus was later identified as *Phyllactinia corylea* (Pers.) Karst.

Grout (7) accepted Burrill's identification. He found that the perithecia matured late in the season and were usually found on the shoots, seldom on the leaves, which he suggested might account for the rarity of their collection and the confusion in nomenclature.

In 1894 Pammel (6) called attention to the disease in Iowa, stating that it was of common occurrence. He recommended the use of Bordeaux mixture instead of ammoniacal copper carbonate as a spray. In a later publication (8) he discussed the confusion in nomenclature and suggested that it is doubtful whether perithecia of *Podosphaera oxyacanthæ* were ever actually seen on the apple in this country.

The early confusion of the identity of the fungus was cleared up by Salmon (9) in 1900. He definitely referred the fungus to *Podosphaera leucotricha*.

The first report of the disease from the State of Washington was by Lawrence (10) in 1905. He described the different species of powdery mildews occurring in the State but did not recognize *Podosphaera leucotricha*.

In 1910 Stewart (11, p. 318-321) reported that he had found no other species than *Podosphaera leucotricha* on apples in New York. He found the disease chiefly on water sprouts and nursery stock, but also found it on the terminal growth of trees 36 years old. He noted that the Chenango and Black Ben Davis varieties are particularly susceptible.

In 1914 Ballard and Volck (12) published a very complete description of the occurrence and control of the disease in the Pajaro Valley of California, where the climatic conditions are particularly favorable to the development of the disease in serious epidemic form. They found that fully 90 per cent of the foliage of susceptible varieties, such as Yellow Newtown and Yellow Bellflower, was frequently diseased. They found that Bordeaux mixture gave very poor mildew control. Copper acetate and copper oxychlorid were effective against the mildew, but caused injury to the fruit and foliage. Dilute lime-sulphur solution and solutions of sulphids in general were likewise injurious. About 125 different materials were tested for foliage spraying, and as a result it was found that sulphur in some finely divided form was the most efficient. Specific directions were given for the preparation of an "iron-sulphid" spray whereby the soluble sulphids so injurious to foliage in that climate were eliminated. Attention was called to the importance of pruning out diseased twigs as a supplemental aid in control. The important relation between

tree vigor and susceptibility to mildew was shown and experiments were reported which demonstrated the possibility of foliage stimulation through spraying with various compounds.

THE CAUSAL ORGANISM.

The cause of apple powdery mildew is the fungus *Podosphaera leucotricha* (E. and E.) Salm. Another species of *Podosphaera*, *P.*

oxyacanthae (DeC.) DeBary, has been reported as the cause of this mildew in some eastern localities, but the writer has never found it on the apple in the Pacific Northwest.

The two species can not be distinguished except in their perfect stage, when marked differences are observed. In the case of *Podosphaera leucotricha* there are two types of appendages on the perithecia.

The basal appendages are short, twining, and rootlike, while the apical appendages are long, slender, stiff, and rarely divided at the tips. Perithecia of *P. oxyacanthae* have appendages placed more or less equatorially and all dichotomously branched at the tips. They are usually all of one type, but rootlike basal appendages are also sometimes found. The distinction between the two species is shown in figures 1 and 2.

It is probable that much of the confusion which has arisen in regard to the identity of the species involved is due to the fact that in most localities the perfect stage is produced but sparingly. However, in the Wenatchee Valley this stage is abundant, and repeated examinations of perithecia have never revealed other than *Podosphaera leucotricha* on the apple. *P. oxyacanthae* has, however, frequently been found by the writer on the native bitter cherry (*Prunus emarginata* (Dougl.) Walpers) and on the western chokecherry (*Prunus demissa* (Nutt.) Walpers) growing in close proximity to apple trees.



FIG. 1.—Perithecium and ascus of *Podosphaera leucotricha* (E. and E.) Salm. (The former is magnified 80 times and the latter 420 times.)



FIG. 2.—Perithecium and ascus of *Podosphaera oxyacanthae* (DeC) DeBary. (The former is magnified 80 times and the latter 420 times.)

DISSEMINATION OF THE FUNGUS.

In the Wenatchee Valley the spread of the fungus during the growing season is largely dependent on the prevalence of dews. Light rains occasionally occur, but moisture for most of the spore germination is found in the dews, which are of almost nightly occurrence. While the humidity of the air in the Wenatchee Valley is usually very low, it is much higher in the orchards which are being irrigated. The daily range of temperature varies between 25 and 30 degrees F. during most of the early part of the season, and often it is even greater; consequently, dews are frequent and occur in the orchards when other sections are free from them.

Spore dissemination is doubtless accomplished by the agency of the wind. During the early part of the season strong winds are of common occurrence and often blow steadily for days. The branches of the trees are whipped about, and the conidia are scattered around and lodged on tender young leaves and shoots. With the coming of nightfall and dews, favorable conditions for spore germination arise and infection proceeds.

Beetles were often found feeding on the mildew, and they may be responsible for some of the spread of the fungus; but they were never found in sufficient numbers to indicate that they were important agents in its dissemination.¹

The perfect stage of *Podosphaera leucotricha* begins to appear as early as the middle of June, when black speckled patches of perithecia form in the felted mycelium on twigs, leaf petioles, and mid-ribs (Pl. I, fig. 1), and occasionally on the fruit.

The perithecia have been observed from year to year in an attempt to determine definitely whether they play any appreciable part in the dissemination of the fungus. The dates of the earliest collection of perithecia in the Wenatchee Valley during the course of this investigation are as follows:

In 1915, on June 22, three months after the appearance of the first leaves.

In 1916, on June 13, two months after the appearance of the first leaves.

In 1917, on June 29, two months after the appearance of the first leaves.

Twigs bearing perithecia were brought into the laboratory at frequent intervals in the spring for examination to determine the date at which the spores were shed. None of the perithecia were found ruptured until fully a month after conidia had become abundant on the current season's growth. Frequently no ruptured perithecia could be found until after new perithecia had developed on the current season's growth. Early in the spring it was difficult to break

¹ Identification of the insects discovered feeding upon the mildew has been made by Mr. E. J. Newcomer, of the Bureau of Entomology, as follows: The most abundant, a ladybird (*Psyllobora borealis* Casey); the next common, a small, pointed, black and brown beetle (*Pentaria nubilia* Le Conte); and the rarest, *Anthicus nitidulus* Le Conte.

the perithecia under a cover glass for microscopic examination, but after soaking in water for 24 hours they were much more easily broken, indicating that rainfall would facilitate natural ascospore dispersal. However, rainfall adequate for this purpose is always lacking in the Wenatchee Valley at this season.

Repeated attempts were made to inoculate tender young foliage with ascospores obtained from perithecia of the previous season's growth. A suspension of spores was sprayed on Jonathan leaves with an atomizer. Some of the leaves were inclosed in glassine bags in order to increase the humidity, while others were left exposed. The work was done between the middle of May and the first of June, when the disease was actively spreading in the orchards. The results were always negative. It would appear from these studies that the ascospores play little, if any, part in spreading the disease and that they are unnecessary to the overwintering of the fungus. This conclusion is in agreement with the results of the investigations of Ballard and Volck (12) in the Pajaro Valley of California and the earlier work of Galloway (3).

DESCRIPTION OF THE DISEASE.

In the Wenatchee Valley the writer has found the disease in its conidial and perithecial stages on twigs, foliage, and fruit of the apple, and occasionally also on pear twigs and foliage. It sometimes attacks the blossoms, and in this case frequently the entire blossom cluster, with its attendant leaves, is involved. Affected flowers are dwarfed and hypertrophied and set no fruit. The petals are deformed, are of a greenish or yellow color, and soon become covered with a powdery coating of spores. (Pl. I, fig. 3.)

The first appearance of the disease is usually manifested in small grayish or white feltlike patches of mycelium on the under sides of the leaves, which become crinkled and curled. (Pl. II, fig. 1.) Often the presence of the fungus can be detected before the appearance of the felted mycelium by the mottled color of the infected leaves, accompanied by a corrugation of their surface. The patches covered by the fungus rapidly enlarge, and generally the entire leaf becomes covered with the felted mycelium and a powdery coating of spores. When very young leaves are attacked they have a tendency to increase in length but not in breadth and gradually become somewhat folded longitudinally. (Pl. I, fig. 1 and Pl. II, fig. 1.) Infected leaves become greasy and eventually so brittle and parched that they fall from the tree. The mildew spreads rapidly down the petiole of the leaf to the twig, which becomes covered with mycelium and spores. Twig growth is soon checked, and in severe infections the twig is killed outright. (Pl. II, fig. 2.) In the Wenatchee Valley, trees covered with terminals killed by powdery mildew are frequently seen after a season of severe infection.

A serious phase of the disease is found in the case of twigs stunted but not killed. New leaves are infected as rapidly as they appear. Buds formed on such twigs are infected by the overwintering mycelium, and in the spring the fungus resumes activity when the leaves unfold, thus performing a function vital to the spread of the disease in carrying the fungus over from season to season. On such twigs the internodes are much shortened and the lateral buds are crowded together. (Pl. II, figs. 3 and 4.) These buds are characterized by a purplish red color and an elongated shape, and they are always delayed in opening from a week to 10 days behind normal buds. (Pl. II, figs. 4 and 5, and Pl. III.)

In cases of severe infection the formation of new fruit buds is prevented and the following season is one of a light crop or no crop at all. Vegetative growth, however, is favored by the absence of a fruit crop; hence, during such a season the trees are given an opportunity to recuperate their vigor and resist the mildew for the time being. But the following year an increased crop is produced, and mildew, again being favored by reduced vegetative vigor, resumes virulent activity and so tends to produce a periodicity of crops that is very undesirable.

The effects of fruit infection are to dwarf the apple and produce a russetting of the skin beneath the mycelium. (Pl. I, fig. 2.) Fruit infection usually occurs early in the season. Active infections on apples after the skin has become hardened have not been observed, and it is therefore probable that danger of such injury is past before the apple is half grown. Infected apples often show elongated stems, while the basins are generally russeted.

SUSCEPTIBILITY OF VARIETIES.

The varieties of the apple found to be most susceptible to the disease in the Wenatchee Valley are Pryor Red, Jonathan, Newtown, Black Ben Davis, Grimes, Esopus (*Spitzenburg*), Fameuse (Snow), and Stayman. No variety appears to be immune, but among the least susceptible are Winesap and White Pearmain. Of these varieties the Pryor Red and Fameuse are not commercially important in the Wenatchee Valley.

IMPORTANCE OF THE DISEASE IN THE PACIFIC NORTHWEST.

Apple powdery mildew occurs in all of the apple-growing regions of the Pacific Northwest, but its economic importance in any of them varies from year to year. Investigations by the writer have shown that the disease is of little economic importance in the Willamette Valley of Oregon and the sections of Washington west of the Cascade Mountains. In these sections infection seems to be confined

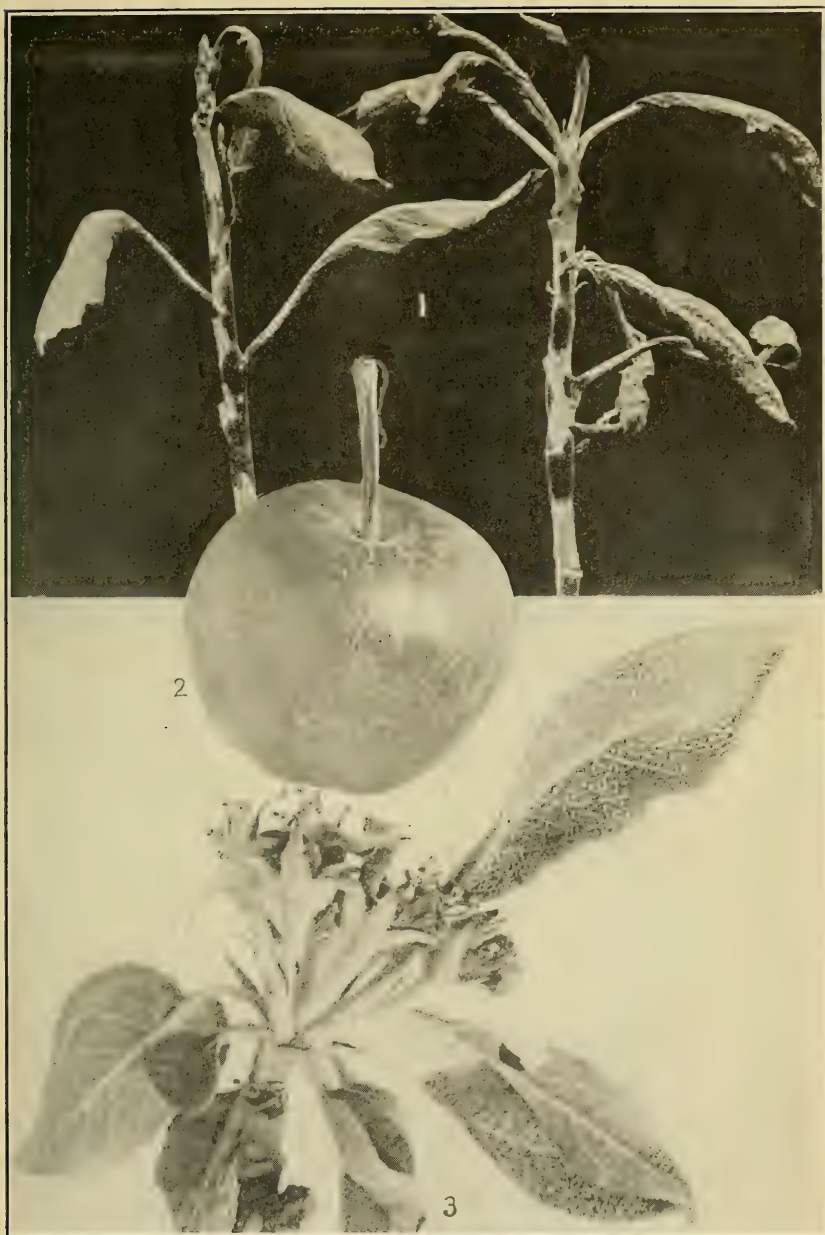
to watersprouts and terminals and has not been observed to be as severe as that often met with in the irrigated regions. Where apple scab is prevalent, as in these more humid sections of the Northwest, the ordinary sprayings with lime-sulphur solution for scab control are effective against mildew, and its control in these sections, therefore, presents no unusual difficulty. In such districts as the Spokane Valley, Wash., the Hood River valley, Oreg., and other sections where natural rainfall can be relied upon for part of the moisture necessary for tree growth and where spraying for apple scab is generally practiced, the growers and horticultural inspectors are agreed that apple powdery mildew is of little or no economic importance. However, in the hot interior valleys, where irrigation is entirely depended upon for moisture supply and where fungicidal spraying has been regarded as unnecessary, the disease has demanded serious attention, and the development of a safe and effective spraying schedule has been attended with peculiar difficulties. Reports of the State horticultural inspectors indicate that serious loss is often experienced. Mr. C. W. Gilbreath, State horticultural inspector in the Walla Walla (Wash.) district, is authority for the following statement regarding the disease:

The damage from apple powdery mildew in this district grew heavier each succeeding year and reached its maximum in 1915. As a result many orchards showed a reduction in crop of 25 to 50 per cent. Jonathan and Newtown are the most susceptible varieties.

That the disease is equally serious in the Yakima Valley, Wash., where the largest acreage of apple orchards in the Northwest is found, is indicated by the following statement of Mr. H. E. Waterbury, State horticultural inspector for the district:

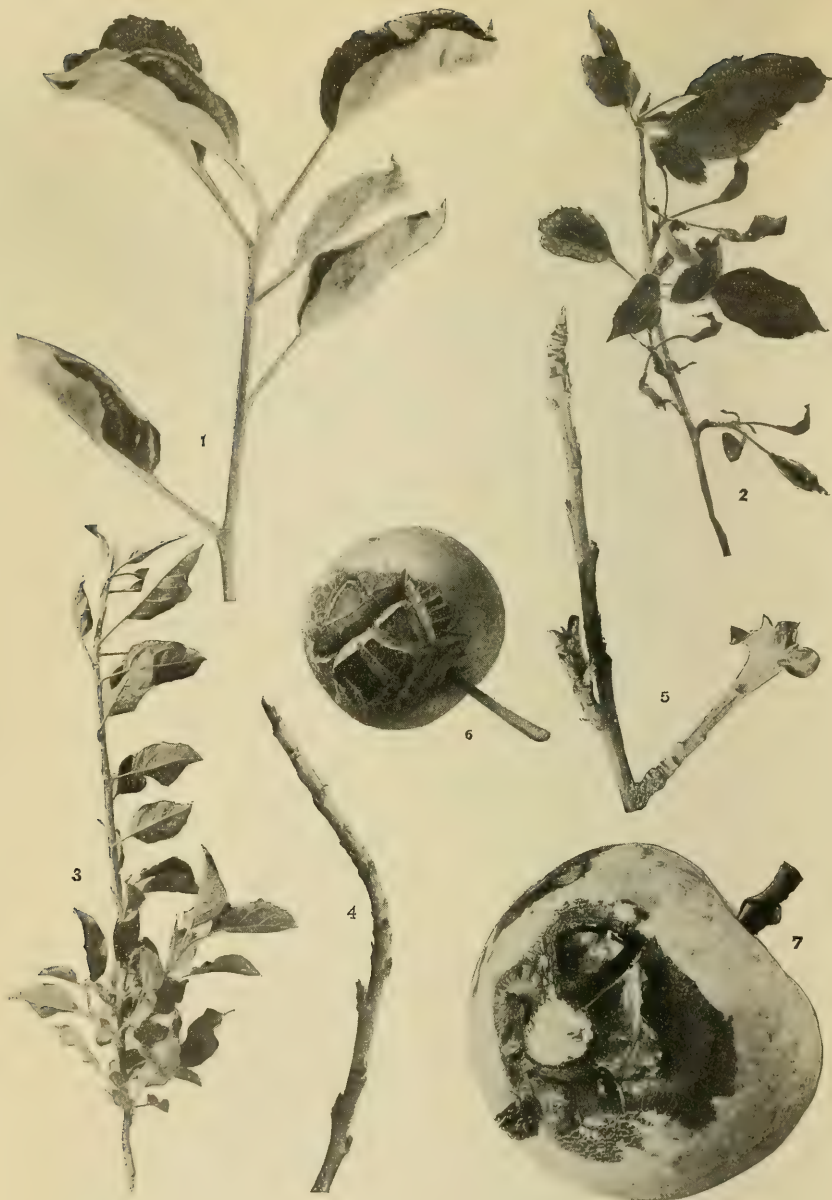
Mildew is prevalent all over the valley on certain varieties, such as Jonathan, Spitzenburg, Newtown, and Rome. The loss occasioned is chiefly loss in vitality, which can scarcely be measured. I do not know of any orchards that do not have some mildew. There has been considerable loss from the so-called mildew scratches (russeting) on the fruit, which has reduced the grade. In some places the Black Ben Davis was so badly marked that fully 25 per cent had to be culled.

Observations by the writer in the Wenatchee Valley indicate that orchards often have shown a reduction of fully 75 per cent of the crop as a result of mildew infection and that frequently nearly all of the new wood growth is attacked, while foliage infection may reach 75 to 90 per cent. Its damage was most severe in many parts of the valley in 1914 and 1915, but each year sees appreciable losses in some orchards due to mildew infection. In 1915 many crops of Jonathan and Black Ben Davis were complete failures, due to the severity of the 1914 infection, while many other varieties were seriously damaged through fruit russeting, foliage infection, and twig blighting. Alarm over impending damage became so general



APPLE POWDERY MILDEW—I.

FIG. 1.—A late stage of foliage infection on Pryor Red watersprouts. Note that many of the leaves have been shed and that those remaining are covered with conidia and are somewhat folded longitudinally. The twigs are covered with mycelium, embedded in which may be seen the dark patches of perithecia, usually located at the base of a leaf and extending up on the petiole. FIG. 2.—Mildew russeting of a Black Ben Davis apple, August, 1916. FIG. 3.—Mildewed blossom cluster from a Pryor Red tree. Note the abundance of conidia over leaves and blossoms and the deformity of the blossoms.



APPLE POWDERY MILDEW—II

FIG. 1.—Portion of the terminal growth of a Black Ben Davis tree, showing an early stage of foliage infection. FIG. 2.—Branch of a Jonathan tree, showing a terminal spur killed by an infection of the previous year and three spurs blighted during the current season. This branch had been sprayed with lime-sulphur solution and the mildewed leaves were severely burned, while the healthy foliage was unharmed. FIG. 3.—Branch of a Pryor Red tree, showing two years' growth, with lateral buds on the portion infected during the first year pushed out into spur growth. Note the shortened internodes. FIG. 4.—Terminal growth on a Pryor Red tree, showing shortened internodes on the infected portion. The noninfected buds are swelling, while those infected are still dormant. FIG. 5.—Portion of a branch of a Pryor Red tree, showing noninfected cluster buds opening and considerable expansion of healthy foliage, while infected leaf buds near the tip of the branch are still nearly dormant. FIG. 6.—An apple, showing injury resulting from the application of sulphur-dust sprays in the Yakima Valley in 1917. FIG. 7.—Pryor Red apple, showing sulphur injury, the type of injury which may be expected to follow applications of sulphur sprays after the advent of hot weather in the arid valleys of the Pacific Northwest.



APPLE POWDERY MILDEW—III.

Branch from a Jonathan tree, showing a terminal twig killed by the infection of the previous year. Note that the petals are beginning to fall from the healthy blossoms on the lower portion, while the blossoms from the infected buds near the terminal twig are not yet open.

in 1915 that for the first time in the Wenatchee Valley systematic spraying for a fungous disease was undertaken.

In general, the methods followed were based upon the recommendations of Ballard and Volck (12) for the Pajaro Valley of California; but since the climatic conditions under which they found soluble sulphids injurious to foliage were not prevalent in the Wenatchee Valley, the somewhat laborious process of removal of these compounds from the iron-sulphid spray was not attempted and a modified formula was used. (See formula 7, p. 11.) A considerable quantity of commercial spray preparations was also used. According to a report of Mr. O. T. Clawson, then State horticultural inspector for the Wenatchee district, the following quantities of spray materials were sold for mildew spraying in 1915:

Commercial sulphur pastes.....	17, 850 pounds.
Lime-sulphur solution	11, 600 gallons.
Iron sulphate (for making iron-sulphid spray) ----	31, 000 pounds.

SPRAY INJURY.

It has not been difficult to control the mildew effectively with any one of several of the sulphur spray materials commonly employed for spraying, but their use during the intensely hot summer weather in the arid districts of the Northwest has invariably been attended with severe fruit burning and some foliage injury.

The importance of climatic factors on spray practices in mildew control has been pointed out by Ballard and Volck (12). However, the difficulty experienced in the Pajaro Valley of California, i. e., defoliation and the dropping of fruit caused by sulphur injury, is seldom met with in the irrigated regions of the Northwest, apparently because of the absence of the foggy weather which is so prevalent in the Pajaro Valley. Sulphur burning on the fruit is found to be the chief reaction induced by climatic conditions in the irrigated sections of the Northwest. Fruit dropping following sulphur injury is only occasionally met with, and foliage injury usually is of minor importance when it occurs at all. However, sulphur spotting of the apples has often resulted in more loss than the mildew would have caused. Growers have therefore largely abandoned attempts to spray for the disease until a safe spraying program could be developed.

Sulphur spotting is always confined to apples on the south and southwest sides of the trees and involves only those apples exposed to the direct rays of the sun during the hottest part of the day. Apples shaded by the foliage are never affected.

In the Wenatchee Valley no injury has resulted from sulphur sprays applied before the middle of May. Sprays applied after this date have generally resulted in the fruit burning as soon as hot weather starts, and sprays applied early in June have invariably

resulted in injury. In some cases intense burning sunlight has not occurred until fully two weeks after the spraying was completed, but still severe burning of the fruit resulted.

The adoption of adequate spraying methods is largely dependent on the safety with which they may be used. The data secured on injury in connection with the use of various sprays during the course of the experiments reported below will therefore be of value in pointing out the weather conditions under which burning occurs, the type of injury resulting, and the time at which the sprays may be safely applied. These data are presented in connection with the experiments herein reported.

ORCHARD SPRAYING EXPERIMENTS.¹

The orchards used were adjacent to each other and for the purposes of this work can be considered as one. The trees used were a solid block of the Pryor Red and Jonathan varieties, the experimental plats each consisting of adjacent rows of seven trees each, while the Black Ben Davis plats comprising a like number of trees were located in double rows extending across the orchard. The trees were 14 years old at the beginning of the experiments in 1915.

The Pryor Red trees have a very open habit of growth, and although they had been cut back severely to bring them into more workable shape they still had a spread of about 30 feet and were about 30 feet high. When in full foliage they required about 25 gallons of spray material per tree. The Black Ben Davis trees were not spread out as much, but were more compact and dense. They required about 20 gallons of spray material each. The Jonathan trees were smaller than those of the Black Ben Davis and more open, requiring about 10 to 15 gallons of spray material per tree. All had been infected with mildew for several years, the disease being especially severe in 1914, when the crop of the Pryor Red trees was reduced to an average of 2 bushels each, although the trees were otherwise capable of producing at least 30 bushels. The Black Ben Davis and Jonathan trees had produced a somewhat heavier crop than those of the Pryor Red, but in every case the foliage and twig growth had been seriously infected and many terminal branches had been killed.

The experiments were undertaken to determine—

- (1) The most effective fungicides for use against apple powdery mildew.
- (2) The most desirable dates for spraying.
- (3) The possible toxic effects of the various spray materials tested.

A high-power spraying outfit of 200-gallons capacity was employed, a pressure of 200 to 250 pounds was maintained, and eddy-

¹ These experiments were carried out at Wenatchee, Wash., in the orchards of the V. & W. Land & Improvement Co. and of Mr. A. P. Kornbau, to whom acknowledgment is due for many courtesies extended during the course of the investigations and for active cooperation at all times.

chamber nozzles of the "driving-mist" type were always used. One line of hose was operated from the top of the sprayer, where special attention was directed toward covering the terminal branches in the tops of the trees and the outside parts of the trees. Another line of hose was operated from the ground and directed against the interior parts of the trees and upward against the under side of the leaves. In this manner an endeavor was made to cover completely all of the vegetative and fruit surface on each tree and obtain as complete protection as the different spray materials could afford. The details of the experiments are presented in Tables I to IV.

The materials tested are listed below, with a statement as to the manner of their preparation or dilution. In connection with each is given the formula number referred to in the spraying schedules.

List of the spray materials tested, showing the composition of the formulas used.

Formula 1.—Commercial lime-sulphur, 34° Baumé, diluted 1½ to 50.

Formula 2.—Commercial lime-sulphur, 34° Baumé, diluted 1 to 50.

Formula 3.—Commercial lime-sulphur, 34° Baumé, diluted 1 to 75.

Formula 4.—Commercial lime-sulphur, 34° Baumé, diluted 1 to 100.

Formula 5.—Self-boiled lime-sulphur, 8-8-50. Add 8 pounds of sifted sulphur to 8 pounds of stone lime, slaking in a barrel. Stir well, and add sufficient water from time to time to keep it from burning. After ebullition ceases, dilute to 50 gallons and strain into the spray tank, when it is ready for use. In practice it is best to make up enough for 150 to 200 gallons at once.

Formula 6.—Iron sulphid (Ballard's formula). Dissolve 10 pounds of iron sulphate in a barrel containing 50 gallons of water. Add lime-sulphur solution until no more precipitate forms. Allow the precipitate to settle and drain off the supernatant liquid. Again fill the barrel with water, stir up the precipitate, and allow to settle, and then drain off the clear liquid as before. Continue this washing process until the yellow color disappears from the clear liquid. Make up to 50 gallons for stock solution. For spraying, stir the stock solution well and dilute 10 gallons in 90 gallons of water to make 100 gallons of spray.

Formula 7.—Iron sulphid (Wenatchee formula). Slowly add 2 pounds of granulated iron sulphate to 100 gallons of water in the spray tank, keeping the liquid well agitated. The iron sulphate goes into solution very quickly. Add 3 quarts of lime-sulphur solution (at a strength of 34° Baumé) and use immediately.

Formula 8.—Colloidal sulphur.¹ Dissolve one-half pound of cheap glue in hot water and add to 50 gallons of water in the spray tank. With the agitator run-

¹This formula was adapted from a rather meager description of a method for preparing colloidal sulphur contained in the Gardener's Chronicle, Aug. 7, 1915, by J. M. Hector and S. J. M. Auld, of University College, Reading, England. They employed this material against American gooseberry mildew at Heston, England, but a complete report of their work has not been published. In a letter to the writer, dated Mar. 10, 1916, Prof. Hector furnished the formula used by them. It differed from the one here described in that they employed gelatine instead of glue and hydrochloric acid instead of sulphuric acid, and they made up a stock solution, which was diluted for spraying. Prof. Hector stated that the chief objection to its general use was its expensiveness. However, by the substitution of glue and sulphuric acid, as employed in formula 8, its cost is greatly reduced. The formula as used at Wenatchee has been satisfactorily employed against apple scab in the Willamette Valley, Oreg., and against prune brown-rot in Clarke County, Wash., in experiments carried on by the Office of Fruit-Disease Investigations.

ning, add $1\frac{1}{2}$ gallons of commercial lime-sulphur solution; then add commercial sulphuric acid until the yellow color is almost but not entirely replaced by white. It usually requires about 0.9 pint of sulphuric acid for $1\frac{1}{2}$ gallons of lime-sulphur solution. When arsenate of lead is to be used in combination with this material it should be added after the acid. Colloidal sulphur spray made up in this manner analyzes approximately as follows, depending upon the composition of the lime-sulphur used: Polysulphid sulphur (calcium as sulphur), 0.09 per cent; thiosulphate sulphur (calcium as sulphur), 0.08 per cent; sulphate sulphur (calcium as sulphur), 0.08 per cent; free sulphur, 0.41 per cent; insoluble matter other than sulphur, 0.009 per cent.

Formula 9.—Finely ground sulphur material of the following composition: Water, 41.44 per cent; sulphur, 55.15 per cent; organic matter (in the form of glue), 1.94 per cent; ash, 1.47 per cent. Dilute to 7 pounds to 50 gallons of water.

Formula 10.—Finely ground sulphur material of the following composition: Water, 14.82 per cent; sulphur, 76.72 per cent; organic matter, 1.80 per cent; ash, 6.66 per cent. Dilute to 6 pounds to 200 gallons of water.

Formula 11.—Sodium-sulphur material of the following composition: Sodium polysulphid, 56.84 per cent; sodium thiosulphate, 36.56 per cent; sodium sulphate, 0.66 per cent; free sulphur, 3.38 per cent; iron and aluminum oxids, 0.14 per cent; water, 2.42 per cent. Dilute to three-quarters pound to 50 gallons of water.

Formula 11a.—Same as formula 11, but diluted to $1\frac{1}{2}$ pounds to 50 gallons of water.

Formula 12.—Sodium-sulphur material of the following composition: Sodium polysulphid, 55.06 per cent; sodium thiosulphate, 40.80 per cent; sodium sulphate, 2.17 per cent; free sulphur, 1.56 per cent; water, 0.41 per cent. Dilute to 1 pound to 50 gallons of water.

Formula 12a.—Same as formula 12, but diluted to $1\frac{1}{2}$ pounds to 50 gallons of water.

Formula 13.—Barium-sulphur material of the following composition: Barium polysulphid, 67.44 per cent; barium thiosulphate, 8.67 per cent; barium sulphate, 5.15 per cent; free sulphur, 17.28 per cent; water, 1.46 per cent. Dilute to 4 pounds to 50 gallons of water.

Formula 14.—Bordeaux mixture, 4-4-50.

Formula 15.—Ammoniacal copper carbonate prepared as follows: Dissolve 5 ounces of copper carbonate in 3 pints of ammonia (25 per cent solution, which should be diluted before using). Dilute to 50 gallons in spray tank.

Formula L.—Lead-arsenate paste, 2 pounds to 50 gallons of water, or powdered lead arsenate, 1 pound to 50 gallons. Where used in combination with fungicides, this designation appears in the spraying schedule, together with the number of the fungicidal formula.

Formula S.—Soap. The addition of 2 pounds of potash-fishoil soap to 50 gallons of spray for a spreader is indicated where this designation appears, together with the number of the fungicidal formula in the spray schedule.

SPRAYING EXPERIMENTS IN 1915.

The results of the spraying experiments conducted in 1915, together with the resulting spray injury and the control established, are shown in Table I.

Aside from the foliage injury shown in Table I, very severe burning of exposed fruits was noted on June 9 on the south and southwest sides of the trees. An estimate of this burning in the various plats was not attempted because of the almost entire absence of a

crop. Stayman Winesap (*Stayman*) trees, bearing a heavy crop and situated alongside the Black Ben Davis used in this experiment and sprayed by the orchard owner with iron sulphid (formula 7), showed on this date about 30 per cent of exposed fruit on the south and southwest sides very severely burned. Besides this, defoliation to the extent of 50 per cent in many instances had taken place, and a heavy drop of fruit had been caused. Subsequent observations indicated that this variety is particularly subject to injury of this nature.

TABLE I.—Results of spraying experiments for the control of apple powdery mildew at Wenatchee, Wash., in 1915.

Variety and plat.	Spray formula. ^a	Dates of application. ^b	Foliage injury. ^c				Foliage infected.
			On Apr. 28.	On June 4.	On July 29.	Total.	
Black Ben Davis:			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per ct.</i>	<i>Per ct.</i>
No. 1.....	6.....	Apr. 24, May 20, June 15, July 15.			2 <i>d</i>	2	1.4
No. 2.....	7.....	Apr. 24, May 20, June 15, July 15.		(<i>e</i>)	5 <i>f</i>	6	1.5
No. 3.....	{ 1..... 1 L.....	{ Apr. 14, 24, May 20. June 15.....	{ 3 <i>g</i>	{ No in-crease.	{ Slight in-crease.	{ 4	{ .3
No. 4.....	{ 1..... 1 L.....	{ Apr. 24, May 20. June 15.....	{ 5 <i>g</i>	{ 3 <i>h</i>	{ 2 <i>h</i>	{ 10	{ .3
No. 5.....	12a.....	{ Apr. 14, 24, May 20, June 15, July 15.	{ Slight.....	{ 4 <i>h</i> 2 <i>i</i>	{ Slight in-crease.	{ 6	{ .8
No. 6.....	11.....	Apr. 14, 24, May 20, June 15, July 15.	do.....	2 <i>h</i>	do.....	4	.9
No. 7.....	5 S.....	Apr. 24, May 20, June 15.					1.1
No. 8 (check).....		Not sprayed.					35.1
Pryor Red:							
No. 9.....	{ 1..... 1 L.....	{ May 20, June 15. Apr. 24.....	{ 20 <i>j</i>	{ No in-crease.	{ No in-crease.	{ 20	{ 2.8
No. 10.....	{ 9..... 9 L.....	{ May 20, June 15. Apr. 24.....	{	{	{	{	{ 6.5
No. 11.....	{ 13..... 13 L.....	{ Apr. 24, July 15. May 20, June 15.	{	{	{ 2 <i>d</i>	{ 2	{ 6.1
No. 12.....	{ 11..... 11 L.....	{ Apr. 24, May 20, June 15. July 15.....	{ Slight tip burning.	{ Less than 1 per cent.	{ Slight in-crease.	{ 2	{ 12.6
No. 13.....	{ 12a..... 12a L.....	{ Apr. 24, May 20, June 15. July 15.....	{ do.....	{ 2 <i>i</i> 5 <i>k</i>	{ 8 <i>h</i>	{ 16	{ 14.9
No. 14.....	7.....	Apr. 24, May 20, June 15, July 15.			1.....	1	10.6
No. 15 (check).....		Not sprayed.					20.1

^a For composition of sprays used, see pp. 11-12.

^b Buds in the "pink" (just before full bloom), Apr. 14; petals fallen, calyx not yet closed, Apr. 24; other applications at the time of regular codling-moth sprayings.

^c Foliage injury expressed in percentage of leaf-surface reduction.

^d On southwest side of trees.

^e Very slight leaf spotting.

^f Increase on southwest side of trees.

^g Leaf spotting and margin burning.

^h Increase.

ⁱ Defoliation.

^j Defoliation (consisting only of infected leaves).

^k Leaf spotting.

Since climatic factors are known to play such an important part in the development of spray injury, the following data will be of interest in connection with the injury noted. The records of the

Washington section of the Weather Bureau show the following conditions prevailing at Wenatchee during the period when spray injury occurred:

Measurable precipitation.

April, none.

May, 1.77 inches, distributed over May 1, 2, 9, 10, 11, 14, 17, 23, 24, 27.

June, 0.21 inch, distributed over June 10, 11, 12, 23.

July, 0.28 inch, distributed over July 4, 8, 14, 26, 27.

Mean maximum and minimum temperatures.

Month, 1915.	Maximum.	Minimum.	Month, 1915.	Maximum.	Minimum.
	° F.	° F.		° F.	° F.
April.....	70.3	42.2	June.....	80.1	53.5
May.....	68.2	46.0	July.....	86.4	57.9

The maximum temperature was between 80° and 90° F. on April 16, 17, 18, and 19, on May 4, 6, 7, and 8, on June 3, 6, 7, 13, 14, 15, 20, and 21, on July 5, 7, 8, 17, 18, 26, 29, and 30; between 90° and 100° on June 4, 5, 22, 23, 29, and 30, and on July 1, 4, 19, 20, 24, 25, and 31; and above 100° on July 2, 3, 21, and 23.

The above temperatures are shade temperatures. The temperatures on fruits exposed to the direct rays of the sun were naturally much higher. Tests made to indicate what this difference might be showed that the temperature was 20 to 30 degrees higher in the sun. From this it appears that the sun temperature ranged well above 100° F. on five successive days (June 3-7) just before the appearance of the fruit burning. No other excessive temperatures were recorded between the date of the last spraying and the appearance of the injury. With the continuance of the hot weather the injury was observed to increase to some extent, but most of the fruit exposed to direct sunlight was injured at the start. There was no indication that the scanty precipitation had any effect on spray injury either to fruit or foliage. The foliage injury appeared to be the result of toxic action of the wet sprays, probably intensified by the bright sunlight, since it began to appear so shortly after the application.

It was a rather difficult matter to arrive at an accurate or representative measure of the control established, especially in the case of infected leaves and twigs, which constitute the principal manifestation of the disease. The variation in the crops of fruit was so great among the different plats that no data could be secured on fruit russeting; hence the results had to be measured by the condition of the vegetative parts. An empirical estimate of the degree of infection is largely influenced by the personal equation, and an inspection of all the foliage and twigs was manifestly impossible in an experiment of this magnitude. Actual counts were therefore made to show the

amount of mildew on definite branches of each tree, thus presenting a fair average of conditions over the plat. This method removed the personal equation and allowed the results to be placed on a percentage basis for comparison. In detail the method employed was as follows: An equal number of representative branches were inspected in the tops and around the lower parts of the trees in each plat; each leaf cluster was taken as a unit, and if any of its leaves showed active mildew infection the unit was so counted. Several thousand such units were examined in each plat about a month after the last spraying. The results, as shown in Table I, indicate the effectiveness of the sulphur sprays, and particularly of lime-sulphur solution, in controlling apple powdery mildew. On trees sprayed with lime-sulphur solution the mildew infection was reduced to a negligible quantity, while the check trees were badly diseased. The less favorable results obtained from the use of the other materials can be attributed partly to the fact that they did not possess as efficient wetting power as the lime-sulphur solution, a point which will be more fully discussed in a later paragraph. However, in the case of the sodium-sulphur sprays the poor results were doubtless influenced largely by the relatively low concentration of polysulphids and free sulphur, which can be regarded as the active ingredients.

SPRAYING EXPERIMENTS IN 1916.

The results of the spraying experiments conducted in 1916, together with the resulting spray injury and the control established, are shown in Table II. In 1916 most of the Pryor Red trees were sprayed with the same materials as in 1915, but the Jonathan and Black Ben Davis trees, which were not included in the 1915 experiments, were given two applications of iron sulphid, formula 7 (see p. 11) by the owner of the orchard.

In the spraying experiments in 1916 only a negligible amount of foliage injury developed early in the season. Only about 5 per cent of tip burning was found prior to June 22 in plat 13. On that date, however, some injury appeared in nearly all plats. Sulphur spotting of the fruit began to appear on June 18, and by June 20 a considerable portion of the exposed fruit which had been sprayed with sulphur preparations was severely burned. As in 1915, the injury was confined to the portions of the tree receiving the direct rays of the sun in the hottest part of the day. The extent of the injury was estimated by actual counts of several hundred apples on the affected portion of each tree. It appeared to be most severe where the deposits of spray material were heaviest. In considering the fruit injury it was found that high temperatures had again prevailed between the time of the completion of the last spraying (June 10) and the date of the first appearance of the sulphur spotting on the fruit (June 18).

Thermograph records during the period from June 8 to 18 revealed the following temperatures:

Maximum shade temperatures.

Date, 1916.	Maximum.	Date, 1916.	Maximum.
	° F.		° F.
June 8.....	90	June 14.....	97
June 9.....	72	June 15.....	100
June 10.....	81	June 16.....	102
June 11.....	87	June 17.....	100
June 12.....	90	June 18.....	82
June 13.....	95		

There was no measurable precipitation during this period. The results again emphasized the danger of applying sulphur sprays when hot, burning sunlight is expected to prevail.

TABLE II.—*Results of spraying experiments for the control of apple powdery mildew at Wenatchee, Wash., in 1916.*

Variety and plat.	Spray formula. ^a	Dates of application. ^b	Spray injury. ^c						Foliage infected.
			On June 22.		On Aug. 1.		Total.		
			Foliage.	Fruit.	Foliage.	Fruit.	Foliage.	Fruit.	
Jonathan:			<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>	<i>Per ct.</i>
No. 1.....	{ 5 S 5 SL	Apr. 22..... May 10, June 10.	1	18	(d)	(d)	1	18	1.1
No. 2.....	{ 6 6 L	Apr. 22..... May 10, June 10.	1	10	(d)	(d)	1	10	1.4
No. 3.....	{ 2 2 L	Apr. 22..... May 10, June 10, July 21.	2	10	(e)	(e)	3	10	.4
No. 4.....	{ 3 3 L	Apr. 22..... May 10, June 10.	3	12	(d)	(d)	3	12	.3
No. 5.....	{ 4 4 L	Apr. 22..... May 10, June 10.	1	13	(d)	(d)	1	13	.5
No. 6.....	{ 8 8 L	Apr. 22..... May 10, June 10.	5	21	(d)	(d)	5	21	.2
No. 7 (check)		Not sprayed							4.0
Pryor Red:									
No. 8 ^f	{ 7 7 L	Apr. 22..... May 10, June 10.	5	37	(d)	(d)	5	37	1.1
No. 9 ^f	{ 1 1 L	Apr. 22..... May 10, June 10.	1	19	(d)	(d)	1	19	1.0
No. 10 ^f	{ 9 9 L	Apr. 22..... May 10, June 10.		25	(d)	(d)		25	1.5
No. 11 ^f	{ 13 13 L	Apr. 22..... May 10, June 10.	2	43	(d)	(d)	2	43	.7
No. 12 ^f	11a	Apr. 22, May 10, June 10.	1	32	(d)	(d)	1	32	1.4
No. 13 ^f	11 aL	do.....	5	35	g 50	(d)	55	35	1.5
No. 14 ^f	12	do.....		17	(d)	(d)		17	1.2
No. 15.....	{ 10 10 L	Apr. 22..... May 10, June 10.		22	(d)	(d)		22	1.1
No. 16 ^f (check)		Not sprayed							16.2
Black Ben Davis:									
No. 17.....	14 S	July 21.....							7.1
No. 18.....	{ 2 2 L	Apr. 22..... July 21.....			(h)	(h)	(h)	(h)	9.4
No. 19 (check)		Not sprayed							15.1

^a For composition of sprays used, see pp. 11-12.

^b Buds in the "pink" (just before full bloom), Apr. 22; petals fallen, calyx not yet closed, May 10; other applications at the time of regular codling-moth sprayings. Where lead arsenate is not shown in the schedule for the applications on May 10 and June 10, separate applications of this material were made following the fungicidal spraying, in order to avoid possible spray injury from combining sprays reputed to be chemically incompatible.

^c Foliage injury expressed in percentage of leaf-surface reduction; fruit injury expressed in percentage of injured apples found on the south side of the trees.

^d No increase.

^e Slight increase.

^f Trees sprayed in the same manner as in 1915.

^g Increase.

^h Slight injury.

An experiment begun after the development of the fruit burning and designed to test Bordeaux mixture for late application showed that while some measure of control could be established by the use of this spray, it was objectionable because of the heavy deposit of spray material which remained on the apples until picking time in October and prevented proper coloring. Apples in plat 17 lacked about 50 per cent of the red color which had developed on unsprayed fruit of the same variety.

Lime-sulphur solution was applied late in July to fruit which had no sulphur spotting and which it was thought might have sufficiently hardened the skin to be resistant to sulphur burning. The results, however, demonstrated that injury might still occur from applications of lime-sulphur as late as July 21.

Severe foliage injury developed in plat 13 after midsummer. This injury was the result of the combination of the sodium-sulphur material and lead arsenate, as is indicated by the fact that no late injury developed in plat 12, where the lead arsenate was omitted. The results prove the incompatibility of lead arsenate and the sodium-sulphur sprays.

The disease control established in 1916 on Pryor Red trees reflected the cumulative effects of spraying for two years with the same materials, except in the case of plat 15, where a finely ground sulphur material had been substituted for the iron sulphid used the year before. For some reason very little mildew developed on the Jonathan trees, although in 1915 they had been as badly infected as the Pryor Reds. The method of measuring the control established was the same as that followed in 1915. Many of the trees yielded a fair crop of fruit, especially on the Jonathan plats; but among the Pryor Red trees the crop was uneven, and no attempt was made to obtain data on fruit russeting. The results again showed the effectiveness of sulphur sprays in controlling mildew and indicated that the benefits of these sprays are cumulative.

SPRAYING EXPERIMENTS IN 1917.

The results of the spraying experiments conducted in 1917, together with the resulting spray injury and the control established, are shown in Table III. These experiments were confined to Pryor Red trees, which, with the exception of the checks, were not included in similar plats in 1916.

As a result of the demonstration in the earlier work of the injurious effects of spraying with sulphur preparations during the season of hot, burning sunlight, the experiments in 1917 were planned to determine (1) what degree of control can be established by careful and thorough spraying with sulphur sprays before the danger period and (2) what sprays, if any, can be substituted for the sulphur materials, especially during the hot weather.

There was no injury from the copper sprays, and again foliage injury from sulphur sprays was negligible, while as a result of late spraying sulphur spotting of the fruit resulted in material loss. A period of hot weather again preceded the first appearance of fruit injury, as is shown by the following statement of the maximum temperatures recorded by a shaded thermograph in the near vicinity of the experimental plats, covering the period between the last spraying on June 11 and the appearance of severe fruit burning on June 19.

Maximum shade temperatures.

Date, 1917.	Maximum.	Date, 1917.	Maximum.
	° F.		° F.
June 11.....	74	June 15.....	98
June 12.....	81	June 16.....	91
June 13.....	87	June 17.....	79
June 14.....	95	June 18.....	90

TABLE III.—*Results of spraying experiments for the control of apple powdery mildew on trees of the Pryor Red variety at Wenatchee, Wash., in 1917.*

Plat.	Spray formula. ¹	Dates of application. ²	Spray injury. ³						Infected.	
			On June 19.		On July 9.		Total.		Foliage.	Fruit.
			Foliage.	Fruit.	Foliage.	Fruit.	Foliage.	Fruit.		
			Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.	Per ct.
No. 1.....	2.....	May 9.....	1	33	(4)	(4)	1	33	1.0	
	2 L.....	May 22.....								
	June 11.....	June 11.....								
No. 2.....	2.....	May 9.....							2.4	1.5
	2 L.....	May 22.....								
	L.....	June 11.....								
No. 3.....	2.....	May 9.....							2.5	
	2 L.....	May 22.....								
	14 LS.....	June 11.....								
No. 4.....	8.....	May 9.....	4	45	(4)	(5)	4	45	1.8	.5
	8 L.....	May 22.....								
	June 11.....	June 11.....								
No. 5.....	15.....	May 9.....							5.5	.9
	15 L.....	May 22.....								
	June 11.....	June 11.....								
No. 6.....	15.....	May 9.....							5.8	2.0
	15 L.....	May 22.....								
	L.....	June 11.....								
No. 7.....	14 S.....	May 9.....							4.0	1.2
	14 SL.....	May 22.....								
	June 11.....	June 11.....								
No. 8.....	14 S.....	May 9.....							8.7	2.0
	14 SL.....	May 22.....								
	L.....	June 11.....								
No. 9.....	9.....	May 9.....		19		(4)		19	2.2	.9
	9 L.....	May 22.....								
	June 11.....	June 11.....								
No. 10.....	9.....	May 9.....							1.9	.8
	9 L.....	May 22.....								
	L.....	June 11.....								
No. 11.....	9.....	May 9.....							2.2	.4
	9 L.....	May 22.....								
	15 L.....	June 11.....								
No. 12..... (check)		Not sprayed							17.4	6.8

¹ For composition of sprays used, see pp. 11-12.

² Buds in the "pink" (just before full bloom), May 9; petals fallen, calyx not yet closed, May 22. June 11 application at the time of regular codling-moth spraying.

³ Foliage injury expressed in percentage of leaf-surface reduction; fruit injury expressed in percentage of injured apples found on the south side of the trees.

⁴ No increase.

⁵ Heavy drop of injured apples.

The method of measuring the degree of control of foliage infection was the same as in the earlier work. The results again showed the effectiveness of the sulphur sprays and indicated that in seasons like that of 1917 good mildew control may be established by careful and thorough spraying with either lime-sulphur solution, colloidal sulphur, or sulphur in some other finely divided form, if the fungicides are applied at the time the buds are in the "pink" and again as soon as the petals have fallen. These experiments also demonstrated that there is little difference in the efficiency of Bordeaux mixture and ammoniacal copper carbonate for mildew control, but both are less efficient than the sulphur sprays. In the case of the Bordeaux mixture, the same objection arose as in previous years, i. e., apples sprayed with it failed to develop a good red color. For this reason, therefore, if it is necessary to spray for mildew after the advent of hot, burning sunlight, ammoniacal copper carbonate is to be preferred to the sulphur sprays.

In 1917, for the first time since the experimental work was begun, a fair crop of fruit was obtained on the Pryor Reds and gave the first opportunity to obtain data on the effects of spraying in the reduction of mildew russetting of the fruit. While the Pryor Red variety is less subject to russetting than some others, and while there was only a small amount of the trouble even on the check trees, the results, as shown in Table III, indicate that the russetting can be eliminated by proper spraying. This is a matter of considerable importance with such solid-color and high-grade varieties as Grimes, Jonathan, Newtown, and Esopus (*Spitzenburg*), and with others where the marking is prominently displayed, and causes a loss of grade and lowered returns. The efficiency of the different sprays in preventing mildew russetting of the fruit proved to be about the same as in the case of foliage infection.

In 1917 it was also possible for the first time to compare the cumulative effects of the different sprays used in previous years in the prevention of bud blight and in insuring a crop of fruit. These data were obtained only in the case of the Pryor Red variety and are presented in Table IV. The plat numbers refer to the designations of the plats in 1916.

TABLE IV.—Average yield of fruit per tree of the Pryor Red variety in 1917, showing the cumulative effects of different sprays used in previous years for the control of apple powdery mildew at Wenatchee, Wash.

Plat.	Average yield.	Crop increase over check.	Plat.	Average yield.	Crop increase over check.
	<i>Bushels.</i>	<i>Per cent.</i>		<i>Bushels.</i>	<i>Per cent.</i>
No. 8.....	18	50	No. 13.....	20	66
No. 9.....	22	83	No. 14.....	11	.....
No. 10.....	18	50	No. 15.....	16	33
No. 11.....	15	25	No. 16.....	a 12	.....
No. 12.....	17	42			

a Check.

The unsprayed trees were located adjacent to the sprayed trees and all were of the same age and size, and except for the spraying all were treated alike; yet those in plat 9, where the mildew had been most effectively controlled by spraying with lime-sulphur solution, produced an average of 83 per cent more fruit than the checks, and other sprayed trees also yielded greatly increased crops.

INJURY TO FRUIT AND FOLIAGE.

Only a small amount of foliage injury was usually found accompanying the fruit spotting. The foliage injury generally developed so soon after the application of the sprays as to indicate that it was induced by the wet sprays. However, hot, burning sunlight undoubtedly increased foliage injury as well as fruit spotting. The addition of lead arsenate to the sodium-sulphur sprays also resulted in increased injury and demonstrated the incompatibility of these spray materials.

The general appearance of the fruit injury or sulphur sunburn was the same in all plats. (Pl. II, fig. 7.) The injury was confined to apples exposed to the direct rays of the hot midday or early afternoon sun. The injured area was of a reddish brown color, usually sharply marked but of irregular outline, and soon became depressed. The affected skin became wrinkled, hard, and leathery, often scurfing off or becoming traversed by cracks which extended deep into the flesh of the apple. The injury most often appeared in the calyx region, probably due to the collection there of much of the spray material. Deposits of spray material usually were clearly discernible over the injured areas.

The conditions under which this fruit injury occurred were identical in each of the three years of the experiment, i. e., it followed the advent of hot, burning sunlight, and only those fruits which were exposed to the direct rays of the sun at the hottest part of the day were affected. The burning was generally more severe where the sulphur was applied in its free state. This fact, together with the delay in the appearance of the injury until after the occurrence of hot, burning sunlight, indicates that the burning of the fruit is not the result of any caustic action of the various sulphids at the time the fruit was wetted. The exact manner in which sulphur sunburn takes place has not been demonstrated.

During the course of the spraying experiments several of the trees developed the "collar-rot" disease, and others suffered severely from drought at certain periods. In such cases, where the vitality of the tree was reduced, the spray injury, especially the foliage injury, was much increased.

In view of the recent revival of dusting for fungous-disease control in certain sections of the United States, the question arises as to what

reaction might be expected from the application of sulphur dusts in the production of sulphur spotting. There was no opportunity for investigating this point in the work at Wenatchee, but since it was demonstrated that the sulphur spotting of the fruit is the effect of hot sunshine on sulphur *per se* and not the result of toxic action of sulphids in solution, there appears to be no reason why the injury should be mitigated by the use of sulphur dusts instead of liquid sprays. Confirmatory evidence on this point is furnished by Mr. F. E. De Sellem, formerly State horticultural inspector in the Yakima Valley, Wash., who reported to the writer very severe fruit spotting as following the application of sulphur dust in 1917. (Pl. II, fig. 6.) The dust was a mixture of powdered lead arsenate and superfine sulphur, such as ordinarily has been used in recent dusting operations in the Eastern States. A power dusting machine was used in making the applications, and the climatic conditions under which the injury occurred were reported to be similar to those which obtained in the Wenatchee Valley when the injury occurred there.

Recent observations of Hundley (14) indicate that in the Yucaipa Valley, Cal., slight sulphur spotting may occur when the hot sunshine is delayed for as long a time as 60 days after spraying. Hundley found fruit injury resulting from sulphur applied in several of the forms used in the experiments at Wenatchee, and he records a marked difference in susceptibility to injury in orchards at different altitudes. He also found those trees most susceptible to spray injury which were low in vitality either because of drought or some other condition.

Apparently the application of sulphur in any form as a spray material for apples is dangerous in a hot, dry climate during the summer season, for in the production of fruit "spotting" or sulphur sunburn high temperature and burning sunlight are the controlling factors.

SPRAY MATERIALS.

In these experiments the lime-sulphur solution appeared to spread better than any of the other materials tested except colloidal sulphur. Lime-sulphur solution possesses great powers of penetration through the felted mycelium and spore coating, and it appeared that much of its beneficial action was due not only to its spreading qualities but to its immediate caustic effect, which destroyed the mycelium and conidia of the fungus. This conclusion is in agreement with the results noted by Eyre and Salmon (13) in their investigations of the fungicidal properties of certain sprays when used against mildews. They demonstrated that, against mildews, solutions of polysulphids act fungicidally as such and not by virtue of the sulphur which

is deposited when they decompose. However, it is certain that such deposits of sulphur on healthy parts act in a protective manner against potential infections. This being true, the advantages of lime-sulphur solution are at once apparent, for not only does it exert an immediate effect against existing infections, but by its deposition over healthy parts free sulphur is soon made available and distributed where protection is needed.

It was found that colloidal sulphur possessed greater spreading power than any other material tested. The uniformly excellent control established by its use is doubtless to be traced to this fact. It appears that this material combines the most desired elements for control, since it not only possesses excellent spreading qualities and thereby deposits a very uniform coating of almost ultramicroscopic sulphur particles to form a protective coating over healthy parts, but at the same time it possesses in its excess lime-sulphur solution sufficient causticity to produce an immediate effect on the fungous mycelium and conidia. With the exercise of intelligent precautions in its preparation there would doubtless be no reason for not advocating its use on a commercial scale in general orchard practice, especially where mildew infection is severe. However, since good results attend the use of commercial lime-sulphur solution it is doubtful whether many orchardists would go to the trouble of making the colloidal sulphur.

With the iron-sulphid sprays, the finely ground sulphur materials, and the sodium-sulphur materials, from one-fourth to one-third more spray material was required to cover the same surface with an efficiency approximating that of either colloidal sulphur or lime-sulphur solution. This apparently was due largely to the greater surface tension and interfacial tension of these materials, giving them less ability to wet the foliage and twigs, especially when covered with mildew. This also resulted in lessened spreading power, and consequently many places inaccessible to the direct force of the spray when applied were not reached and remained unprotected. The addition of soap, when not chemically incompatible, would increase the spreading power and the value of such sprays. The poorer results obtained from the use of these sprays were also partly due to their lower concentration of active fungicidal ingredients.

Bordeaux mixture, if combined with soap, spreads very readily, but it proved objectionable in the climate of the Wenatchee Valley because of the pale fruit color developed under the heavy spray coating. Black Ben Davis apples sprayed with Bordeaux mixture failed to develop more than 50 per cent of the normal red color of this variety and were discriminated against on the market on this account. In the Wenatchee Valley there are no rains to wash off the spray coating, and fruit sprayed with Bordeaux mixture in July still

retains it at picking time in the fall. Moreover, the control established by the use of this material did not approach the results obtained from the more efficient of the sulphur sprays.

Self-boiled lime-sulphur offered the same objection as Bordeaux mixture in that heavy deposits of spray material remained on the apples and prevented their proper coloring. It likewise proved less efficient than several of the other materials. It appeared to give some protection to healthy parts after application, but it failed to destroy existing infections, and conidia were abundantly pushed up through the spray coating.

Ammoniacal copper carbonate closely approximated the fungicidal action of Bordeaux mixture and left no objectionable deposit on the apples. For this reason it is preferred to Bordeaux mixture for use in spraying during hot weather.

The barium-sulphur preparation appeared to approximate the action of commercial lime-sulphur solution against mildew, but it proved more toxic to fruit and foliage during hot weather

SUMMARY OF CONTROL MEASURES.

The results noted demonstrate—

- (1) That sulphur sprays are superior to Bordeaux mixture or ammoniacal copper carbonate for mildew control.
- (2) That, except possibly in seasons of exceptionally heavy infection, apple powdery mildew can be commercially controlled by sprays applied before hot weather starts and consequently before there is danger of sulphur spotting of the fruit.
- (3) That while Bordeaux mixture and ammoniacal copper carbonate may be less efficient as control agents than lime-sulphur solution or other sulphur sprays, their use may be advisable in years when continued spraying may be necessary.
- (4) That ammoniacal copper carbonate is preferable to Bordeaux mixture for this purpose, since it does not leave an objectionable deposit on the fruit and thereby prevent normal coloring.
- (5) That in the case of sulphur sprays efficiency is dependent on (*a*) the immediate caustic effect of the sprays on the fungous coating and (*b*) the deposit of a protective coating of free sulphur over noninfected areas. Both *a* and *b* are largely dependent on the spreading qualities of the sprays, which, in turn, are dependent on the surface tension and the interfacial tension of the sprays.

DORMANT SPRAYS.

A possible influence of winter or dormant sprays of strong lime-sulphur solution on the overwintering fungus has been suggested, but these experiments do not point to any such influence. Each year just after the buds had begun to swell, but before the appearance of the first leaves, the check trees were thoroughly sprayed with lime-sulphur solution at a strength of $3\frac{1}{2}^{\circ}$ Baumé. These trees always

became infected many times as severely as those which received in addition to the dormant spray the proper foliage spraying through the active growing season, as shown in Tables I, II, and III. The reason for this lack of effect of the dormant spray is to be found in its inability to reach the overwintering mycelium in the buds. If the perithecia alone were concerned there might be some beneficial effect from such sprays, but since these are known to be unnecessary in carrying over and disseminating the fungus little is to be gained by their destruction.

PRUNING EXPERIMENTS.

Many growers have endeavored to control mildew by pruning out the infected parts, both in the winter and while the infections are active during the growing season. By the removal of infected twigs the immediate effect secured is to eliminate a source of infection for the remainder of the season; the permanent effect is to prevent the overwintering of the fungus and the spread of the disease the following year. Hence, if all mildewed shoots and infected buds could be removed, the disease would doubtless be eradicated, and the practice of such pruning could be depended upon to hold the disease in check. However, in cases of severe infection, eradication by this method would involve not only the serious mutilation of the trees and often the destruction of practically all the new growth, but also a great amount of labor. In order to demonstrate the practicability and efficiency of this method the following experiments were undertaken.

Six Jonathan trees were very carefully gone over before they came into leaf, and every sign of mildew that could be detected was removed. At this time the terminals infected the previous year and bearing infected buds could be detected by their silvery gray color and glistening appearance in the sunlight, their stunted growth, and the reddish color and slender, elongated shape of their lateral buds, which were also less advanced than normal healthy buds.

After the active growing season began it was found that in spite of all the care in pruning, these trees were liberally covered with infected leaves coming from widely distributed buds on older branches that had escaped detection earlier in the year. To have distinguished these with certainty as infected at that time would have involved an inspection of every single bud on the trees, a task manifestly impracticable. When this result became apparent the experiment was continued to demonstrate the benefits to be derived from dormant pruning as a supplemental aid to foliage spraying during the growing season. The trees were sprayed at intervals of four weeks until the middle of July, receiving in all four applications of lime-sulphur solution diluted $1\frac{1}{2}$ to 50, the same as plat 3 in 1915. For comparison, six unpruned Jonathan trees in the immediate vicinity of the pruned

plat were also sprayed in like manner. At the end of the season it was plain that while there was less infection on the trees which had been pruned, the difference in control was certainly not sufficient to pay for the extra labor involved in the very careful examination of the dormant trees. These results are contrary to those obtained by Ballard and Volck (12) in the Pajaro Valley, Cal., and are undoubtedly due to the difference in spraying practices followed. On account of climatic conditions it is impossible in the Pajaro Valley to use lime-sulphur solutions or other sulphur sprays known to possess the power of easily wetting and penetrating the mildew. However, in the Wenatchee Valley full benefit could be had from the wetting effects of the lime-sulphur solution, and consequently better control could be established by spraying.

GENERAL NOTES ON THE CONTROL OF THE DISEASE.

It was always found that mildew first appeared before the blossoms opened—on the foliage expanding from dormant buds. By the time the trees were in full bloom conidia were being shed in abundance. This indicates that an application of fungicides must be applied earlier, and the experiments have shown that the first application should be made at the same time as in the case of apple scab, i. e., just after the cluster buds have separated, while the blossom buds are in the pink. There is little to be gained by an earlier application, because so little foliage is expanded, and the delay of the infected buds prevents an earlier spread of the disease. Most of the blossom infection results from mycelium carried over in the blossom buds from the previous year and not as a result of conidial dissemination of the current year. It is not, therefore, probable that a spray applied at the time mentioned would have much beneficial influence in preventing blossom infection, but it is extremely important in cleaning up incipient foliage infection and in protecting the healthy leaves. If this treatment is followed by others at such intervals that all of the new foliage is protected as it expands, adequate protection is gained. The experiments indicate that after the "pink" spray the disease can be held in check in ordinary years by combining the fungicides with the first two regular applications of lead arsenate used in codling-moth control. If supplemental spraying is required, the applications should be made at intervals not greater than four weeks.

There is a strong prejudice in the Wenatchee Valley against the combination of lead arsenate and lime-sulphur or other sulphur sprays. This seems entirely unwarranted, for in the course of these experiments no detrimental effects were observed from the use of the combined sprays except as noted in the case of the sodium-sulphur materials. It has been repeatedly demonstrated

in other parts of the country that the combined spray is not only the most practical method of applying insecticides and fungicides when both must be used, but that the combined spray is more efficient than separate applications.

Orchard studies indicate that tender young foliage is most easily infected and that terminal growth is especially susceptible. The striking thing about a badly infected tree is the preponderance of mildewed terminals, which give it a whitened appearance. Most of this infection takes place early in the season, up to the time that vegetative growth is largely completed, but infection continues as long as new foliage is being formed. It frequently happens in the irrigated sections of the Northwest that a secondary vegetative growth takes place in the latter part of the summer, after the resumption of irrigation following a period of drought. In infected districts such new growth is usually attacked by mildew after its spread had apparently ceased with the checking of the earlier vegetative growth.

CONCLUSIONS.

(1) Apple powdery mildew is generally prevalent in the arid regions of the Pacific Northwest. It attacks foliage and twigs, reducing the vitality of the tree, and also attacks the young fruit, causing an objectionable russetting of the skin. It has often caused a reduction of more than 50 per cent of the crop in infected orchards, and it causes a further loss in a reduction of vitality that is impossible to estimate.

(2) The disease is caused by the fungus *Podosphaera leucotricha* (E. and E.) Salm., which winters over in dormant buds in mycelial form. Ascospores can not be regarded as essential to the propagation of the fungus. It is spread by conidia disseminated by the wind, and possibly to some extent by insects. Dews furnish sufficient moisture for spore germination.

(3) Dormant sprays of lime-sulphur solution at a strength of $3\frac{1}{2}^{\circ}$ Baumé (a dilution of about 1 to 9, when lime-sulphur testing 34° Baumé is used) have had little or no effect on the overwintering fungus and have not hindered the spread of the disease.

(4) Pruning out diseased shoots can not be depended upon alone to effect control of the disease when it is present in epidemic form.

(5) The disease is readily controlled by applications of sulphur sprays during the growing season. However, after the advent of burning sunshine, which can be expected in the hot interior districts of the Pacific Northwest after the first of June, the use of sulphur spray materials is certain to cause severe fruit injury.

(6) Bordeaux mixture is less effective than sulphur sprays against powdery mildew and leaves such a heavy deposit on the fruit that it

does not color properly. Ammoniacal copper carbonate is practically as effective as Bordeaux mixture against this disease and leaves no deposit on the fruit to hinder coloring; it is therefore preferable to Bordeaux mixture for such use.

(7) The results of mildew control are cumulative, and with the establishment of adequate control the crops of fruit are substantially increased.

(8) These experiments have shown that the disease can be effectively controlled by spraying in accordance with the following schedule, which is recommended:

First application. Spray with lime-sulphur solution diluted 1 to 50 when the cluster buds have separated, but before the blossoms open—the “pink” spray.

Second application. Spray with the same material in combination with lead arsenate for codling-moth control as soon as the petals fall and before the calyx is closed.

Third application. Spray with ammoniacal copper carbonate in combination with lead arsenate for codling-moth control about three or four weeks after the second application.

If subsequent applications are necessary they should be made at intervals not greater than four weeks, using ammoniacal copper carbonate as a fungicide.

In spraying it is important to cover every part of the leaves and twigs, and special attention should be given to the terminals. A pressure of 200 to 250 pounds should be maintained, or sufficient to drive the spray in a fine mist through the tops of the trees. High pressure is especially important if spray materials are used which have poor spreading qualities. Eddy-chamber nozzles of the “driving-mist” type should be used.

(9) In the production of sulphur spotting of the fruit, high temperature from burning sunshine is the determining factor. It is believed that the injury is not the result of toxic chemical action of sulphids in solution at the time of spraying, but it probably is due to the heating of the spray deposits to such a degree that death of the adjacent cells occurs, the results being partly due to the physical effects of the heat and partly to the chemical effects of volatilized sulphur compounds.

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A STUDY OF FARMING IN SOUTHWESTERN KENTUCKY.

By J. H. ARNOLD, *Agriculturist.*

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HOW TO MEASURE SUCCESS IN FARMING.

To be successful as a business, a farm should earn a fair rate of interest on the investment and return to the operator fair wages for labor and management after paying all expenses, including depreciation. In the locality under consideration in this bulletin 5 per cent is assumed to be a fair rate of interest on invested capital. It is just about what 68 landlords in this locality averaged from rented farms, and is about what the average reliable real-estate loans would net the investor.

Wages for labor and management are commonly known as labor income. The average labor income of the 342 farms studied was found to be \$356.55. The following is a business statement of the average of these farms showing how labor income is derived:

Total capital (owner's and tenant's capital combined)..... \$17,029.00
Working capital..... 3,494.00

Total receipts..... \$2,896.00
Total expenses, including unpaid family
labor..... 1,688.00

Farm income..... 1,208.00
Five per cent interest on investment (\$17,029)..... 851.45

Labor income..... 356.55

In addition to the labor income of \$356.55, this average farm furnished a part of the family living and a house to live in, the value of which is estimated to be \$500. Besides, an average of \$81 for unpaid labor was charged in expenses, which should be regarded as a part of the income of the family. Thus the total net income of an average family owning their farm might be summarized as follows:

Interest on investment.....	\$851.45
Labor income.....	356.55
Estimated value of family living and house furnished by the farm.....	500.00
Unpaid family labor.....	81.00
Total.....	1,789.00

Labor income is commonly used to measure the business success of one farm as compared with another. It does not always show whether an individual is a successful or unsuccessful farmer.

FACTORS WHICH MAKE SOME FARMS MORE SUCCESSFUL THAN OTHERS.

Two definite objects should be kept in mind when considering successful farming, namely, obtaining profits and maintaining soil fertility. The ordinary diversified farm to a large extent must depend on crop rotations and a proper system of live-stock farming to maintain the fertility of the soil. On nearly all farms in the part of Kentucky studied, however, lime and commercial fertilizers are used to great advantage.

The factors which most directly affect profits are: Size of business, crop yields, returns from live stock, type of farming, diversity, and the selection and proportioning of crops and live stock.

SIZE OF BUSINESS.

A matter of first importance in farming is the size of the business. However skillful or energetic a farmer may be, or however fertile his land, he can not hope for business success if his business is not on a large enough scale. In the area studied 29 farmers on farms under 100 acres in size made an average farm income of \$370 and a labor income of only \$81. Such an income, in addition to what the farm may furnish for the family living and a house to live in, could not be counted as more than a wage. Sixty farms averaging 286 acres in size made an average labor income of \$356, while 46 farms averaging 715 acres in size made a labor income of \$1,133.

The extent to which a farmer may enlarge his business depends on the capacity of the operator to organize and operate a large business, and on available capital and labor. Among the 342 farms studied, \$134,000 was the largest amount of invested capital handled

by any individual farmer. The large diversified farms require a heavy investment in live stock, and experience has shown that handling live stock involves considerable risk, so that farmers hesitate to use their own capital too freely in live-stock investments; for the same reason it is difficult to borrow large amounts for such ventures.

On the farms studied the most common way of enlarging the farm business is by renting additional land. Of the farmers visited, those who rented additional land almost invariably made higher profits than those who farmed only the land they owned. Fifty-five farm owners out of 342 farmers rented additional land and made an average labor income of \$552, while the average labor income of farm owners without additional rented land was \$222. Sixty-eight were tenant farmers, and these made the highest labor income, \$656.13.

The good farmer will aim to make the net earnings of his farm as high as possible. Net earnings are what is left after subtracting from receipts all expenses excepting a charge for rent of land, but including a charge for management.¹ Net earnings as thus defined would be what a farmer could afford to pay a landlord for rent. The average of 342 farmers made the land earn \$3.14 per acre, net. The average of 140 more successful farmers made the land earn \$6.14 per acre. The average of all others, representing the less profitable farms, was \$1.05 per acre. Difference in quality of soil only partly accounted for the difference in land earnings, since all these farms are located on land similar in kind and topography. Neither did the prices of land vary widely on the different farms. The differences evidently were due mainly to farm practice and organization. The farms showing highest earnings per acre were better stocked, had greater diversity, less idle and waste land, and better economy in the utilization of horse labor. Farms over 400 acres in size averaged about 120 productive days' work per horse, while farms under 100 acres in size averaged but about 80 days. The cost of man labor was also lower on the large farms.

CROP YIELDS.

Next in importance to size of business in profitable farming is crop yield. While low crop yields in large measure account for the very low profits on many of these farms, a good many farmers were able to make fair profits in spite of low yields. It is even possible to secure high yields at too great expense. It must always be kept in

¹ When taking the farm records each farmer was asked to estimate the value of his services as manager, not including the labor he performed. The average of these estimates was \$459. The average cost of labor on the farm, including an estimate of the value of the operator's actual farm labor, was \$782. Thus the cost of management was 58 per cent of the labor cost.

mind that the money expended in getting higher yields should increase net returns by more than this expenditure.

In order to secure good crop yields under the system of farming in vogue in the locality under discussion it is necessary to use commercial fertilizer. The practice of liming the land is becoming well established and is a means of rapidly building up its fertility. In order to get proper results from fertilizer and lime, however, the soil must also be kept supplied with humus. Grass and clover are depended on mainly to supply this requisite, but these, sown usually with wheat, frequently fail to make a stand, thus interfering with the usual rotation. In this way the land loses in fertility; and in order to allow it to recuperate, it is often allowed to lie idle a year or more. This fact, in large measure, accounts for idle improved land on many farms.

Many practices for insuring a stand of grass and clover have been tried with more or less success. Among these are the spreading of straw on the land sown to wheat and grass-clover mixture. Another practice is to summer fallow the land. Then, after thoroughly harrowing and packing the seed bed, the grass-clover mixture is sown without a nurse crop. Sometimes land thus prepared is covered with straw, to conserve moisture and protect the young plants. The practice of liming the land, as previously mentioned, has proved to be one of the most effective means of insuring a stand of clover, and when this practice becomes established the problem of maintaining fertility will be largely solved.

Lespedeza, widely known as Japan clover, is finding its way slowly into the system of farming in this locality. It is found growing in most waste places, along highways, and is creeping into the pastures. This legume may be sown with red or alsike clover in the early spring. In places where the soil is too poor for the grass and red-clover mixture, the lespedeza will usually grow, and while it will not get high enough to cut for hay it will furnish pasture, besides holding and enriching the soil. It will reseed each year, thus holding the land indefinitely if not disturbed. It matures later than most meadow grasses and other legumes, thus furnishing good summer and fall pasture. On fertile soil it makes a good hay crop, or it may be cut late in the fall for seed.

The proper stocking of the farm is one of the most important factors in maintaining good crop yields. This depends largely on success in maintaining meadows and pasture. Thus the problem of stocking the farm is closely related to the problem of insuring each year a stand of grass and clover. If the farmers in this region will establish the practice of liming the soil, in order to make the grass and clover crop more reliable, and if they will sow alsike clover and

lespedeza with red clover and raise more live stock, the most fundamental and important problem in farming for this locality will be solved.

RETURNS FROM LIVE STOCK.

While crop yield is one of the more important factors in farming, the return from live stock is just as important in proportion to the amount it contributes to the receipts of the farm. In general, live stock is kept on the farm to serve three major purposes: (1) To increase the value of grain and feedstuffs on the farm by feeding them; (2) to utilize waste products; and (3) to maintain the fertility of the soil. The analysis of 342 southwestern Kentucky farms showed that the profits in farming increased with the increase in the amount of live stock kept on a given area of land. Farms that had the equivalent of one cow or horse to 7 or 8 acres of land were almost invariably more profitable than those that had a higher acreage per animal. The same records showed also that crop yields increased with the increased amount of live stock kept on a given area of land.

An important cause of loss on unsuccessful farms in this region is the waste of feed on live stock, especially of corn fed to hogs. Corn is now a high-priced feed and it occupies a considerable portion of the crop area on each farm, so that unless great care is exercised in feeding it the farm will suffer loss.

A common way to measure profits in live stock is to compare net receipts from live stock (gross receipts less value of purchases) with the value of feedstuffs consumed. The average of 342 farms showed that \$107.57 in net receipts was made for each \$100 worth of products fed. These products were valued at farm prices and included the farmer's estimate of the charge for pasture. The average of the best 39 farms had \$226 net receipts for each \$100 worth of feed consumed and had an average labor income of \$1,155. The average of 46 farms showing greatest loss in feeding was \$33 loss for each \$100 worth of feed consumed. These farms showed a minimum labor income of \$84. A great deal of the material consumed as feed could not be valued, for if not consumed in this way it would have been largely waste.

TYPE OF FARMING.

The usual type of farming carried on in southwestern Kentucky is wheat, tobacco, and general live-stock farming, these enterprises being the three main sources of income. Small farms usually find it profitable to specialize on some particular enterprise, such as tobacco, dairying, or hay. Diversity of crops and live stock, however, is an important factor on such farms. The larger the farm the more important the wheat crop becomes, but successful farms of this type have large

diversity. On farms of 200 to 300 acres in size there is a tendency to make dairying an important enterprise. Of the 342 farms studied, however, only about 24 were regular dairy farms. Most of these sold market milk directly to consumers. Thirty-four farms sold butter, cream to creameries, and some market milk. The farms on which dairying was made a special enterprise were nearly always more profitable than farms without the dairy. The average successful farm of all sizes had more dairy cows than the less successful farms, showing that dairying as a farm enterprise is to be encouraged in this locality. It is doubtful, however, whether the strictly dairy type of farming should be generally recommended, though dairy farms are generally profitable where a market for milk is accessible.

Generally speaking, on large and medium-sized farms, from one-half to two-thirds of the total farm receipts should come from live stock.

Tobacco is an important enterprise on nearly all types of farms. About 12 per cent cent of the crop area on the average small farm is planted to tobacco; on large farms, 6 to 8 per cent.

SELECTION OF ENTERPRISES.

The important crops that have been selected through long experience in farming in this section (about 125 years) are winter wheat, dark tobacco, corn, oats, timothy, and red clover. For many years these have characterized the system of farming. More recently cow-peas, soy beans, and lespedeza have also found an important place. Productive live stock, which have been found profitable to handle, are cattle, hogs, sheep, and poultry. The average successful farm of about 300 acres of improved land will be found to have crops distributed approximately as follows:

Per cent of improved land devoted to pasture and to crops, and per cent of crop area devoted to specific crops.

Distribution of improved land:	Acres.	Per cent.
Crop area.....	225	75
Pasture	75	25
Distribution of crop area:		
Wheat	101	45
Tobacco.....	20	9
Corn.....	55	25
Other cereals.....	12	5
Meadow hay.....	23	10
Miscellaneous crops.....	14	6

About 8 per cent of the land on the average farm is practically waste or idle land. This is a source of great waste on farms in this section. The less the waste or idle land on farms, the greater were the profits. Fifty-five farms averaged 18 per cent of waste land, and the average

labor income of these farms was \$158, as compared with \$356, the average of all farms.

Live stock on the average successful farm of 300 acres of improved land was distributed approximately as follows:

Live stock on average successful farm of 300 acres of improved land.

	Per farm.	Per 100 acres improved land.
Cows -----	6	2
Young stock -----	6	2
Hogs -----	60	20
Stock cattle -----	6	2
Sheep -----	45	15
Poultry -----	150	50
Work stock -----	10	3

Acres improved land per 1,000-pound animal, 6.6.

Ordinarily farms in this section are not as heavily stocked as they should be. The diversified farms on this type of soil should have a carrying capacity of at least one 1,000-pound animal for each 6 to 7 acres of improved land.

DIVERSITY.

A proper diversity of sources of income is an important factor in profitable farming. In the first place, this stabilizes the income from year to year. It is seldom that conditions which make one single crop unprofitable will affect all crops in the same manner. For instance, dry weather during the latter part of May and June may have a bad effect on corn and tobacco, when usually such conditions are favorable for wheat. In the second place, by means of diversity a better distribution of labor is secured. Tobacco furnishes work during every month of the year. Other crops require attention for shorter periods during the growing season. By long experience these various crops have come into an adjustment which meets all conditions in a practical and generally advantageous manner. Of course, on many farms a better adjustment could be secured by more careful planning along the lines indicated by general experience.

Farms between 220 and 300 acres in size proved to be the most efficiently organized among those studied, and had, also, the most profitable degree of diversity. They showed about three-fourths as much of their receipts from live stock as from tobacco. Receipts from wheat and tobacco were approximately equal in amount. About equal amounts were received also from hogs and sheep, and from cows and stock cattle. On farms of this size more receipts come from hogs than from sheep and more from stock cattle than from cows. On small farms—75 to 100 acres in size—receipts came mainly from some one enterprise like dairy products, hay, or tobacco.

Farms of average size—about 300 acres—showed the most profitable diversity when receipts were distributed about equally between wheat, tobacco, and live stock, with a few minor sources of income, such as clover seed, poultry, hay, and corn.

ROTATION OF CROPS.

Probably no other term has been repeated so often in discussing agricultural problems as the term "rotation of crops." On most diversified farms everywhere some kind of crop rotation is practiced. Experience will teach farmers that, except under special conditions, one crop can not profitably be grown continuously on the same plot of ground. When, for various reasons, complete rotation systems can not be carried out and when a sufficient amount of manure is not available to supply the needed humus and plant food, some land usually lies idle a year or more at a time to recuperate. Such a practice is a source of great waste on farms, as already has been pointed out.

When all the land on the farm is about equally adapted to such crops as can be grown in a locality, a quite regular crop rotation develops. Where such crop rotations prevail the farmer can predict with practical certainty the crop which will be grown on a certain field one or two years hence. In the locality where this survey was made, however, though the land is generally level to rolling in topography, there is considerable diversity of soil on different parts of any individual farm. This condition, together with the fact that grass and clover often miss a stand, makes it difficult to follow a definite system of rotation. Thirty-two farmers out of 342 stated that they followed no system. The great majority, however, have some system which they aim to follow. In the majority of cases this was given as corn or tobacco, wheat, and grass and clover. Often a part of the wheat field is plowed after harvest, disked, harrowed, and rolled. This process is called summer-fallowing. In the fall redtop, sometimes with timothy, is sown along with the wheat. The general practice is to sow clover in the early spring. Sometimes clover alone is sown on the wheat land and left to hold the ground only one year, when it is turned under and followed by corn or tobacco. If grasses are sown with the clover and make a good stand, the land may remain in sod two or three years for meadow or pasture. When clover is cut for hay a second growth comes on, which, if the season is favorable, is cut in the fall for seed.

It will thus be seen that the problem of rotations in this locality is very complicated. Instead of the system becoming a mechanical one, as is the case in some sections, the farmer here modifies it each year to suit such conditions as may prevail at the time of prepara-

tion and planting. To follow such a system successfully requires exceptional experience and good judgment on the part of the farmer.

Such being the conditions, the proportioning of crops on the land each year is an important factor in profitable farming in this section. This proportion is in a general way quite uniform on farms of the same size and type and has become very definitely established by custom. Hence the successful farmer in this locality makes the amount of each crop he should grow a matter of first importance, and the rotation must be adapted more or less accordingly.

The building up of the soil by means of lime, commercial fertilizer, legumes, and live stock will undoubtedly result in more regular systems of rotation.

GOOD FARMING INCREASES THE VALUE OF THE LAND.

The average price of land represented by the 342 farms studied was \$64 per acre, ranging generally from \$50 to \$150. The average net earning capacity of the land, as previously stated, was \$3.14 per acre,¹ so that the average price would just about be supported by the earning capacity of the average farm, figuring interest at 5 per cent, or about the net rate which farmers with money to loan can get in this locality. Thus, if the average farm in this community can be made to earn \$5 per acre, the value of land here would be pushed up to \$100 per acre. This fact affords an opportunity for increased profits to the farmer who has skill in growing crops and live stock and who, besides, understands the principles of farm organization for this locality.

THE PRACTICAL VALUE OF STANDARDS OF FARM ORGANIZATION.

In nearly all inquiries made by farmers and others relative to organizing and operating a farm, some or all of the following questions are asked: (1) What crops, and how many acres of each, should be planted? (2) What kinds of live stock, and how many of each kind, should be kept on the farm? (3) How much labor is required to do the work, and how many work animals are needed? (4) How much working capital is needed for live stock, machinery, and supplies? (5) What should be the receipts and expenses for a year's business on the farm? (6) What yields are to be expected from crops, and what returns should be expected from the various kinds of live stock?

Though these can not be answered with precision, all are practical questions which every farmer should carefully consider, and which

¹ As was pointed out on page 3, \$3.14 is what the average farm would earn for a landlord if he rented it. This would be 5 per cent on a valuation of about \$63 per acre.

emphasize the need of standards of organization and practice that are approximately correct for safe and reliable farming, based on the experience of successful farmers.

In asking such questions as these the size of the farm is in mind as a basis for calculating these various factors. In some sections, however, as in the cotton belt, the number of mules or horses available is the basis for organizing the farm business. In sections where dairying is the prevailing type of farming the number of dairy cows is the basis. In most sections, however, where diversified farming is the rule and where the land is comparatively high in price, the basis of farm organization is the size of the farm rather than the number of work stock or dairy stock needed to equip it. Thus, in this locality, where differences in types of farming are based largely on the amount of land available for a farm, and where diversified farming is the rule, the amount of improved land available should be taken as the basis of farm organization.

No farm organization, however well it may measure up to standards based on the experience of the best farmers, can prove successful if the operator is not efficient, if yields are much below the average of the community, if prices of cash crops should be abnormally low, or if live stock should not show a substantial profit on feed consumed. On the other hand, the farm organized on the basis of the experience of the best farmers and operated by an industrious and efficient manager could hardly fail to be successful with average yields and prices.

STANDARD YIELDS AND FARM VALUES FOR IMPORTANT CROPS AND PRODUCTIVE ANIMALS.

Table I shows the average yields and farm values for important crops on the most successful 140 farms in 1915, also the estimated normal yields and farm values of these crops. The figures given for normal yields are based on estimates of 20 to 25 farmers in the locality. In estimating normal farm values the 1915 Yearbook of the United States Department of Agriculture was consulted, and account also was taken of local conditions and the range of prices prevailing for several years past, during which time the writer has been familiar with farm conditions in this region.

It will be observed that the yields for wheat and corn were abnormally low in 1915, the year to which the farm records applied. The yields for tobacco and hay, however, were higher that year than the normal, which to a large extent compensated for low yields of cereals.

Farm values for live stock and live-stock products were generally higher in 1915 than the normal. This is shown in Table II. The normal values were estimated on the basis of prices ruling in the

general markets, account being taken of shrinkage, freight charges, and local conditions.

The weights given for hogs, stock cattle, and lambs are averaged estimates. The production and receipts per cow and the production and receipts per 100 poultry are the averages based on the most successful 140 farms. Twenty-five of the 140 successful farms made the production of milk and butter an important enterprise, and the cows on such farms were rated as dairy cows. On the 115 remaining successful farms the selling of milk and butter was only incidental to the purpose of keeping the cows. On such farms the main purpose is home supply. On all farms poultry were kept mainly to supply food for the family.

TABLE I.—*Yield and farm value of important crops for 1915 compared with estimated normal yields and farm values.*

Crop.	Unit of yield.	Average for 140 successful farms in 1915.		Estimated normal for the locality.	
		Yield per acre.	Value.	Yield per acre.	Value.
Wheat.....	Bushel....	11.27	\$1.10	18	\$0.96
Corn.....	do.....	29.0	.66	35	.60
Tobacco.....	Pound.....	878.6	.0603	850	.07
Hay.....	Ton.....	1.25	14.56	1	12.00

TABLE II.—*Average farm values of live stock and live-stock products for 1915 compared with estimated normal farm values.*

Live stock and live-stock products.	Basis of comparison.	Values and receipts.	
		1915	Normal.
Hogs (200 pounds weight).....	100 pounds.....	\$6.75	\$6.00
Stockers (750 pounds weight).....	do.....	5.50	4.50
Lambs (75 pounds weight).....	do.....	8.00	6.50
Wool (5 pounds weight).....	1 pound.....	.34	.28
Dairy cows (530 gallons per cow).....	Receipts per cow.....	88.50	.....
Average farm cow (370 gallons per cow).....	do.....	22.30	.....
Poultry (62 eggs per hen).....	Receipts per 100 hens.....	46.28	.....

A STUDY OF FIVE INDIVIDUAL FARMS WHICH, IN GENERAL, ILLUSTRATE GOOD STANDARDS FOR THE ORGANIZATION OF FARMS IN THE AREA STUDIED.

AN 89-ACRE TOBACCO FARM.

Improved-land area	acres...	83
Field crop area	do.....	49
Pasture	do.....	34
Business statement:		
Value of owner's land (75 acres)		\$7,000
Value of rented land (14 acres)		1,200
Working capital		1,168
Receipts		1,583

Expenses.....	\$636
Farm income.....	947
Interest on operator's investment, at 5 per cent.....	408
Labor income.....	539

Crops:	Acres.	Yield.	Per cent of crop area.
Corn.....	15	35 bushels	31
Wheat.....	15	10 bushels	31
Tobacco.....	14	821 pounds	28
Miscellaneous crops.....	5	-----	10

Live stock:	Number on farm.	Number per 100 acres of improved land.
Cows.....	2	2.3
Young stock.....	2	2.3
Hogs.....	14	16.0
Poultry.....	200	241.0

Man labor: Approximately 800 days of man labor were required. - No hired labor was employed. Work was done by the operator and family, the total labor employed being the equivalent of about 2.5 year hands.

Horse labor: Approximately 350 days of horse labor were required. Two mules were kept to do this work.

Capital: The average value of owned and rented land was about \$90 per acre. The working capital was \$1,168, or \$14.07 per acre of improved land.

The distribution of working capital was:

Live stock.....	\$619
Machinery.....	201
Feed and supplies.....	198
Cash to run business.....	150

Total..... 1,168

Expenses: The farm expenses amounted to \$630, or about 40 per cent of receipts.

Sources and amount of receipts:

Wheat.....	\$125
Tobacco.....	949
Dairy.....	129
Hogs.....	77
Poultry.....	107
Increase inventory.....	196

Total..... 1,583

Sixty per cent of receipts on this farm were from tobacco, 28 per cent of the crop area being devoted to this crop and more than half the man labor. For these reasons such a farm may be classified as a distinctly tobacco farm.

Receipts were \$19.07 per acre of improved land.

Though the labor income in this instance was not high, it was above the average of the farms surveyed, and the farm could be rated as successful.

The small successful farms varied in type much more than large farms. Some of them specialized on dairying. One farm, 83 acres in size, specialized on meadow hay and made a labor income of \$884.

The 89-acre tobacco farm just analyzed made about the average yield of tobacco. The price obtained, however, was 8¼ cents per pound, which was much higher than the average for that year. This shows that the tobacco must have been of good quality.

It will be noted that while the main source of income was tobacco, five other sources contributed materially to the farm income. Success on a small farm depends much on making the minor enterprises contribute to the income.

A 138-ACRE DIVERSIFIED DAIRY FARM.

Improved land area	acres	136
Crop area	do	97
Pasture area	do	39

Business statement:

Value of owned land (135 acres)	\$13,500.00
Value of rented land (3 acres)	600.00
Working capital	2,975.00
Receipts	2,404.00
Expenses	952.00
Farm income	1,452.00
5 per cent interest on investment	839.00
Labor income	613.00

Crops:	Acres.	Yields.	Per cent of crop area.
Corn	40	32 bushels.	41
Wheat	30	13 bushels.	31
Meadow	8	1½ tons.	8
Tobacco	12	857 pounds.	7
Miscellaneous crops	12		13

Live stock:	Number.	Number per 100 acres of improved land.
Cows	10	7.4
Young stock	8	5.9
Bull	1	---
Hogs	17	12.5
Poultry	100	74.0

Man labor: Approximately 740 days of man labor were required. The operator and one year hand, with some help by the family, did the labor on this farm. The total labor employed was the equivalent of about 2.7 year hands.

Horse labor: Approximately 550 days of horse labor were required for the work on this farm. Two horses and three mules were kept on the farm.

Capital: The land was valued at \$100 per acre. The working capital was \$2,975, or about \$22 per acre of improved land.

The distribution of working capital was as follows:

Live stock	\$1,684
Machinery	366
Feed and supplies	625
Cash to run business	300

Sources and amount of receipts:

Wheat.....	\$400
Tobacco.....	360
Dairy	1,030
Young stock.....	271
Hogs	220
Poultry.....	21
Other sources.....	102
Total.....	2,404

The receipts amount to \$17.70 per acre of improved land. Receipts from the dairy are greater than from any other one source, being 43 per cent of the total. Receipts from the four other major sources were pretty evenly distributed. The selection and proportioning of crops were similar to the common diversified farms. It then may be classified as a diversified dairy farm.

Expenses: Expenses were \$952, or about 40 per cent of receipts.

This farm was well organized for the general dairy type of farming in this locality. About 43 per cent of the total receipts were from dairy cows. The balance of receipts was well distributed to crops and the various kinds of live stock found to be profitable here. This distribution shows proper diversity.

Receipts per cow were \$103, showing good quality for the dairy business. About an equal amount of receipts were from market milk and butter. The average for 24 dairy farms was \$88.50 per cow.

Crop yields were about normal, and the proportioning of crops and live stock conformed fairly well to standards set by the more successful farms in the community. However, if this land had been a general diversified dairy farm there should have been about 14 acres of tobacco instead of 7, and about 30 acres of corn instead of 40.

Both man and horse labor were well utilized. The farm was much better stocked than the average. There were 5.6 acres of improved land to each 1,000 pounds of animals. The average of 342 farms was 20.5 acres per 1,000 pounds of animals. Fifty-four farms, showing less than 10 acres of improved land per 1,000 pounds of animals, had an average labor income of \$621, or nearly twice that of the average farm.

A 160-ACRE DIVERSIFIED GENERAL FARM.

Improved land area.....	acres.....	156
Crop area.....	do.....	126
Pasture	do.....	30

Business statement:

Value of land, at \$80 per acre.....	\$12,800
Working capital.....	6,499
Receipts	5,847
Expenses	2,116
Farm income.....	3,731
5 per cent interest on investment.....	965
Labor income.....	2,766

Crops:	Acres.	Yield.	Per cent of crop area.
Corn.....	25	40 bushels.	20
Wheat.....	40	25 bushels.	32
Oats.....	12	50 bushels.	10
Meadow.....	25	1½ tons.	20
Tobacco.....	20	1,000 pounds.	16
Cowpeas (double crop).....	10	.....	8
Alfalfa.....	4	.....	4

Live stock:	Number.	Number per 100 acres of improved land.
Cows.....	3	1.9
Young stock.....	2	1.3
Stock cattle.....	32	20.5
Hogs.....	46	29.0
Poultry.....	100	64.0

Man labor: Approximately 1,500 days of man labor were required on this farm. About 700 days' labor required by the 20 acres of tobacco was done by a cropper. The remaining 800 days' labor was done by a year hand, the operator, and some family labor.

Horse labor: Approximately 820 days of horse labor were required on the farm. The owner furnished horse labor to the cropper raising the tobacco. Seven work animals were kept on the farm to do this labor—2 horses and 5 mules.

Capital: The value of the land was \$80 per acre. Working capital invested amounted to \$6,499, or about \$41 per acre of improved land.

The distribution of working capital was approximately as follows:

Live stock.....	\$4, 298
Machinery.....	516
Feed and supplies.....	685
Cash to run farm.....	1, 000

Sources and amount of receipts:

Wheat.....	\$1, 250
Tobacco.....	1, 300
Cows.....	130
Young stock.....	225
Stock cattle.....	1, 495
Hogs.....	637
Poultry.....	400
Increase inventory, and other sources.....	410

5, 847

The receipts amount to about \$37.50 per acre of improved land. Receipts are about evenly divided between wheat, tobacco, and live stock, making the type a distinctly diversified general farm.

Expenses were approximately \$13.50 per acre, or about 36 per cent of receipts.

This was an unusually successful farm for the region. Its success was due largely to high crop yield and profits in feeding stock cattle. A large amount of the stock feed came from cowpeas and alfalfa. Twenty-five tons of these products were fed, mostly to stock cattle.

The sources and amount of receipts shown above indicate a good degree of diversity. The proportioning of crops and live stock conform to the standards of the more successful farms. Both man and horse labor were well utilized. The farm was unusually well stocked, there being the equivalent of about one 1,000-pound animal for 3 acres of improved land. These factors indicate excellent organization.

A 315-ACRE DIVERSIFIED GENERAL FARM.

Improved land area.....	acres.....	296
Crop area.....	do.....	200
Pasture.....	do.....	56
Idle crop land.....	do.....	40

Business statement:

Value of land.....	\$23,625
Working capital.....	5,165
Receipts.....	4,777
Expenses.....	1,917
Farm income.....	2,860
5 per cent interest on investment.....	1,440
Labor income.....	1,420

Crops:	Acres.	Yield.	Per cent crop area.
Corn.....	55	40 bushels.	28
Wheat.....	80	10 bushels.	40
Meadow.....	50	1.6 tons.	25
Tobacco.....	11	800 pounds.	5
Other crops.....	4	-----	2

Live stock:	Numbers.	Number per 100 acres of improved land.
Cows.....	7	2.4
Bulls.....	1	-----
Young stock.....	5	1.7
Stock cattle.....	7	2.4
Sheep.....	41	13.8
Hogs.....	42	14.2
Poultry.....	40	13.5

Man labor: Approximately 1,400 man days' labor was required on this farm. Two regular year hands were employed. The equivalent of two year hands was hired as extra labor. Besides this, family labor was utilized equivalent to about one year hand. The operator did no manual labor on the farm.

Horse labor: Approximately 1,000 days of horse labor were required on this farm. Ten head of work stock were kept—2 horses and 8 mules.

Capital: The land was valued at \$75 per acre. Working capital amounted to \$5,165, or about \$17.50 per acre of improved land. Working capital was distributed as follows:

Live stock.....	\$2,636
Machinery.....	1,717
Feed and supplies.....	622
Cash to run business.....	200

Sources and amount of receipts:

Wheat.....	\$700
Tobacco	506
Hay.....	700
Clover seed.....	450
Dairy	508
Heifers.....	140
Stock cattle	555
Sheep.....	210
Hogs.....	328
Thrashing for neighbors.....	530
Increased inventory.....	150
Total.....	4,777

The receipts amounted to \$16.14 per improved acre. About 34 per cent of receipts are from live stock, fairly distributed to stock cattle, hogs, sheep, and dairy cows. The balance of receipts are fairly distributed to wheat, tobacco, hay, clover seed, and outside labor. This distribution would put the farm in the class of diversified general farms.

In spite of low crop yields for wheat and tobacco, this farm was fairly successful for its size. Yields less than normal for two important cash crops—wheat and tobacco—while having a large influence in lowering profits, did not prevent business success, because much larger profits than usual were made on live stock. For every \$100 worth of feed consumed, live stock netted the farm \$201. This was one of the most highly diversified farms studied. Six of the 11 sources of income were nearly of equal value. Diversity is one of the important factors influencing profits in farming. No better illustration of this principle could be given than the results on this farm.

While strong in diversity and quality of the live-stock business, there were some weak points in the organization of this farm. Standards based on the most successful farming would have required 20 to 25 acres of tobacco instead of 11 acres. Best standards would have required also more live stock. Instead of the equivalent of thirty-seven 1,000-pound animals, the number should have been at least 50.

Forty acres of land was idle, showing that the farm was having difficulty in maintaining fertility. Idle land on the farm is an important negative factor in profitable farming in this locality. It frequently determines profit or loss.

A 1,091-ACRE DIVERSIFIED GENERAL FARM.

Improved area.....	acres.....	952
Crop area.....	do.....	602
Pasture area.....	do.....	320
Idle land.....	do.....	30

Business statement:

Value of owner land, 203 acres, at \$75.....	\$15,225
Value of rented land, 888 acres, at \$80.....	71,040
Working capital.....	12,312

Receipts	\$12, 053
Expenses, including \$2,200 cash rent	6, 470
Farm income	5, 583
5 per cent interest on operator's investment	1, 377
Labor income	4, 206

Crops:	Acres.	Yield.	Per cent of area.
Corn	175	30 bushels	29
Wheat	275	13 bushels	46
Meadow	65	1 ton	11
Tobacco	45	750 pounds	7
Cowpeas	30	-----	5
Other crops	12	-----	2

Live stock:	Number.	Number per 100 acres of improved land.
Cows	22	2. 3
Bulls	1	---
Young stock	20	2. 1
Stock cattle	24	2. 5
Hogs	215	23. 0
Poultry	105	11. 0

Man labor: Approximately 4,000 days of man labor were required on this farm. This labor was performed by 7 year-hands, extra labor amounting to 4 year-hands, and the operator.

Horse labor: Approximately 2,700 horse days were required. Twenty-two work stock were kept—4 horses and 18 mules.

Capital: Operator's land was valued at \$75 per acre and rented land at \$80. Working capital was all furnished by operator, amounting to \$12,312, or 12.82 per acre of improved land.

Working capital was distributed as follows:

Live stock	\$5, 645
Machinery	1, 742
Feed and supplies	3, 425
Cash to run farm	1, 500

Sources and amount of receipts:

Wheat	\$3, 610
Tobacco	1, 688
Hay	1, 080
Cows	1, 515
Young stock	355
Stock cattle	855
Horses	330
Pasturing and feeding stock	346
Hogs	2, 223
Other sources	151

Total	12, 153
-------------	---------

Receipts amounted to about \$12.80 per acre. On this farm wheat is the source of highest income. As a rule, in this locality the importance of wheat increases with the size of the farm. Receipts, however, are about equally divided between crops and live stock. The type is largely that of the diversified general farm.

Expenses were \$6,470, including \$2,200 paid in cash rent. This farmer did a successful farm business. Crop yields were somewhat below normal. Profits on live stock, however, were good and above the average, the live-stock receipts being \$145 for each \$100 worth of feed consumed. A great factor in the success of the business was 888 acres of land rented for cash, a little less than \$2.50 per acre. The landlord received, however, about 3 per cent on his investment.

This farm should have carried more live stock to conform to the standards of the more successful farmers. The equivalent of 114 1,000-pound animals were carried, when the number should have been about 150. No sheep were kept. The organization could have been improved if there had been about 150 ewes. This would have about rounded out the stocking of the farm.

Field crops were proportioned approximately according to the standards of the average farm of this size.

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BULLETIN No. 714

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

August 9, 1918

SPOILAGE OF CRANBERRIES AFTER HARVEST.

By C. L. SHEAR and NEIL E. STEVENS, *Pathologists*; R. B. WILCOX and B. A. RUDOLPH, *Scientific Assistants, Fruit-Disease Investigations.*

(The work done in Massachusetts was in cooperation with the Massachusetts Agricultural Experiment Station.)

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INTRODUCTION.

IMPORTANCE OF SPOILAGE AFTER HARVEST.

Three million dollars' worth of cranberries are, on the average, produced annually in the United States. Although effective control measures are practiced by many growers, a considerable portion of the crop, certainly not less than 10 per cent, is lost through fungous diseases before the fruit is picked. Large losses also frequently appear after picking. In some respects this spoilage is more troublesome than that which occurs earlier. Fruit which spoils after it is packed and shipped has cost the grower for handling and packing, and further expense is frequently involved in claims for allowances, shipments refused, inspection, and sometimes reseparating at the market. On the average, at least 15 per cent of the crop is estimated to be lost between the field and the consumer.

A less obvious but even more serious effect upon the demand for and sale of cranberries is that produced by marketing spoiled fruit. "Time and again," says Mr. A. U. Chaney (3, p. 30)¹, "have I no-

¹ The serial numbers in parentheses refer to "Literature cited" (p. 20).

ticed that a retailer who has unsound and unattractive fruit in his store has blocked his sale of cranberries." As the trade becomes more and more critical, not only of cranberries but of other fruits, the time is rapidly approaching when (2, p. 30) "growers must recognize the absolute necessity of producing fruit that will be sound when it goes before the consumer."

PLAN OF THE PRESENT WORK.

The senior writer has carried on investigations of the diseases of cranberries since 1901. During the past two years (1916 and 1917), however, the problem has been taken up with special reference to the losses which occur after picking. Field work and storage experiments have been carried on in Massachusetts and New Jersey; laboratory studies of material shipped from these areas and from Wisconsin, Michigan, Oregon, Maine, and West Virginia have been made at Washington, D. C.; fruit has been inspected and studied in most of the important markets east of the Mississippi River; and experimental shipments have been made from cranberry-growing centers to Washington, New York, and Chicago. So far as practicable, the field work in New Jersey and in Massachusetts has been conducted along similar lines, in order to avoid errors due to peculiar local conditions.

The investigations in Massachusetts have been carried on in cooperation with the Massachusetts Agricultural Experiment Station, the work at the State bog at East Wareham being in charge of Dr. H. J. Franklin (4, 5). Prof. F. W. Morse, of the experiment station, has also taken up certain important phases of cranberry respiration in relation to spoilage. While the investigations are not yet complete, the present paper aims to present the more important results and the conclusions thus far obtained in order that they may be immediately available to cranberry growers.

CAUSES OF CRANBERRY SPOILAGE.

The spoilage of cranberries is due in general to one or more of the following causes: Freezing, insect work, bruising, drying out, natural ripening processes, fungous rots, and smothering. The writers propose to employ the term smothering to designate the pathological conditions produced in fruits by sufficient interference with respiration, whatever the cause of this interference.

As the cause of freezing and the means of its prevention are well understood and the work of insects is outside the province of this paper, these two causes of spoilage will not be discussed.

BRUISING.

Loss due to bruising is by no means confined to actual crushing of berries by careless handling or spilling in sorting or packing houses,

though this is in itself a cause of considerable loss and should be carefully guarded against.

Very important and more difficult to eliminate are the numerous unnoticed injuries occurring in the processes of harvesting, separating (milling), sorting (hand screening), and packing the fruit. It has been shown that these injuries, while too slight to affect the immediate sale of the fruit, indirectly bring about serious losses by starting decay. This relation of bruising to the starting of fungous rot will be considered later.

Slightly injured berries also dry out and shrivel much more quickly than sound fruit. Shrinkage in storage will be reduced, therefore, by care in harvesting and handling the fruit.

DRYING OUT.

Cranberries held in storage will gradually shrink even though no decay occurs. An experienced observer (6, 1913, p. 20) estimates this shrinkage as high as 10 per cent in the case of Early Black cranberries held in common storage at the bog for late trade. A part of this loss is due to the natural ripening processes mentioned below and part in some cases to the actual loss of water by evaporation. Bruising the fruit increases its rate of drying out and shriveling.

The rate at which water is lost by evaporation depends in part directly on the moistness of the air. In tests made by keeping weighed quantities of cranberries in containers with air of known humidity it was found that for any given temperature the loss in weight increased with the decrease in the humidity of the air. (Table I.)

TABLE I.—*Decrease in the weight of cranberries of the Howe variety held for 36 days in air of different humidities at certain temperatures.*

Air conditions.	Relative humidity (per cent).				
	100	80	65	35	a 0
Temperature 5° to 10° C. (41° to 50° F.):					
Loss in weight.....per cent..	0	4	5	6	9
Temperature 2° to 5° C. (36° to 41° F.):					
Loss in weight.....do.....	.5	1.5	3	4.5	6

a Over concentrated sulphuric acid.

It is evident from these results that considerable humidity in the air of the storehouse is desirable to prevent the drying out of the fruit. Under the conditions ordinarily obtaining in cranberry storehouses the humidity is sufficient to prevent any serious loss from drying. In New Jersey the higher temperatures after picking are favorable for drying, and under some conditions of storage fruit kept for a long time may actually shrivel.

It should be mentioned in this connection that in a series of tests extending through both 1916 and 1917, in which cranberries of both

the Early Black and the Howe varieties were kept in containers of known humidity, using a method already described by one of the writers (13), no direct relation was found between the humidity of the air and the amount of rot of the fruit. Berries kept as well in very moist air as in drier air unless they were actually wet.

NATURAL RIPENING PROCESSES.

Like other fruits, the cranberry when picked is a living organism, carrying on its vital activities, which may be referred to in general as ripening processes. Of these processes one of the most important is respiration. Under normal conditions the respiration of a fruit is marked by taking in oxygen and giving off carbon dioxid. In this process the living matter of the fruit is broken down and the berry gradually loses weight. If continued long enough this process would end in the destruction of the berry. It has been demonstrated that respiration goes on more rapidly at high than at low temperatures; consequently, the cooler the berries can be kept without freezing the longer they will live and the better will be their condition.

SMOTHERING.

CONDITIONS WHICH CAUSE SMOTHERING.

In a paper published with the report of the Massachusetts Cranberry Station for 1916 (11) the writers called attention to the spoilage of cranberries caused by insufficient ventilation. As pointed out at that time, cranberries kept in tight cans or in an atmosphere of carbon dioxid lose their crispness and bright color, become dull red and flaccid, and taste bitter. Since this kind of spoilage is apparently caused by conditions which check normal respiration, the writers designate it as smothering. Experience has shown that whenever cranberries of good keeping quality are covered with some inert gas, such as carbon dioxid, buried for some time in a big pile of berries, shut up in a tight container, kept under water, or subjected to other conditions which prevent normal respiration, smothering occurs. The exact causes of this spoilage, as well as the nature of the changes brought about in the fruit, are now the subject of investigation by Prof. F. W. Morse, of the Massachusetts Agricultural Experiment Station.

When berries are under water or under carbon dioxid, death due to smothering occurs in a short time, often in one to two weeks, whereas in tight containers or in large piles it results so slowly that if the berries are of inferior keeping quality fungous rot may destroy them before the effect of smothering appears. In case rot-producing fungi are present, they develop rapidly on the weakened berries, and a mass of rotten fruit results.

WATER STORAGE.

Storing cranberries under water is frequently recommended as a means of keeping them for long periods. Berries stored in this way soon die as a result of smothering. They can not, however, wither, nor do they decay, since the growth of rot-producing fungi is prevented. Water-stored berries do not have the bitter taste characteristic of most smothered fruit and are therefore suitable for cooking if used as soon as removed from the water. Such berries are, of course, unsalable.

The effect of storing cranberries in tight packages and under water as compared with storage in ventilated packages was shown by a series of tests made at the State experimental cranberry bog, East Wareham, Mass. In one experiment, uniform lots of apparently sound berries, of both the Early Black and the Howe varieties, were stored dry in closed bottles, under water in bottles, and in ventilated boxes. The results of this test are given in Table II.

TABLE II.—*Results of storing cranberries under different conditions for 36 days.*

Conditions of storage.	Number of berries.			Total spoiled (per cent).
	Total.	Rotten.	Smothered.	
Temperature 3° to 8° C. (37° to 46° F.):				
Under water, in bottle.....		0	All.	a 100
In closed bottle, dry.....	1,054	777	None apparent.	74
In ventilated box.....	1,364	382	0	28

a As explained in the text, these berries were still fit for cooking.

The results shown in Table II are typical of those obtained in other tests, some of which were carried out at much higher temperatures and with other varieties of cranberries, and have been further substantiated on a commercial scale by shipments in various types of packages and by storage tests. These will be considered later.

PREVENTION OF SMOTHERING.

Smothering may be prevented by ventilation. Berries should be stored in ventilated boxes, never in barrels, and the boxes should be so piled as to allow circulation of air through the berries. Cranberry storehouses should be provided with ventilators, which should be opened whenever cold air can be admitted without danger of freezing. Ventilated packages should be used where practicable. These points are also of importance in the control of fungous diseases and are discussed further in that connection.

FUNGI.

IMPORTANCE.

The writers' observations (10) indicate that rot-producing fungi cause at least one-half of all the loss in cranberries after picking. These fungi are, however, by no means of uniform importance in different regions or in different seasons. A study of a number of neighboring bogs during a single year or of a single bog through a series of years can not fail to impress the investigator with the extreme variation in the loss due to decay.

An illustration of the variation in the amount of rot over a considerable area in different seasons is found in the annual reports of the board of inspectors of the New England Cranberry Sales Co. for the last five years, as given by the chairman, Mr. H. S. Griffith (6). The crop of 1913 was described as "remarkably free from fungous disease"; in 1914 and in 1915 there was a large percentage of unsound fruit; the crop for 1916 was unusually sound up to November 1, after which a noticeable, though not very serious, amount of end-rot developed; the crop for 1917 was in general of good keeping quality, with a small amount of fungous disease. As these inspectors determine the brand of the crops from representative bogs over much of the Massachusetts cranberry area, their reports, no doubt, represent fairly well the condition for the entire region.

The prevalence of rot in some seasons seems to be associated with weather conditions which would favor the growth and spread of fungi. Our knowledge of these relations is too slight, however, to permit of very definite conclusions. Differences in the amount of rot on different bogs or on various portions of one bog are often related either to lack of vigor or to excessive growth of the vines, due to various causes. These relations will be considered later.

PRINCIPAL CRANBERRY FUNGI WHICH CAUSE FRUIT ROTS.

The fungi which cause the decay of cranberries after they are picked are in a large part those which attack the fruit on the vines. The molds which cause decay of such perishable fruits as strawberries and raspberries are rarely found on cranberries and are, therefore, of slight importance.

Among the diseases which are the principal causes of losses of cranberries in storage are early-rot (8), caused by *Guignardia vaccinii* Shear, which is also the cause of scald and blast, and which is especially destructive to fruit on the vines and early in the season in New Jersey; end-rot (9), caused by *Fusicoccum putrefaciens* Shear, common on fruit in storage, especially late in the season and in the northern cranberry regions; bitter-rot, caused by *Glomerella cingulata vaccinii* Shear; ripe-rot, caused by *Sporonema oxycocci* Shear; and blotch-rot, caused by *Acanthorhynchus vaccinii* Shear. Soft-rot,

caused by *Penicillium* spp., is rather common on fruit held late in storage, but is usually associated with other rots, and is not of great importance. Ripe-rot develops at a lower temperature than any of the other rots, except end-rot, and is most frequent in Massachusetts.

CONTROL OF FUNGOUS DISEASES.

Bog Management.

Since all the fungi which cause important storage rots of cranberries are found on the bogs and in large part gain entrance to the berries before they are picked, control measures should begin with the bog. Not all of the factors which determine the abundance of fungi are understood at present; in fact, it sometimes seems as if a bog is free from rot-producing fungi in spite of the treatment it receives rather than because of its management. Certain phases of bog management seem, however, to have a direct relation to the keeping quality of the fruit produced. An excessive growth of vines, whether produced by too much nitrogenous plant food or some other cause, generally results in diseased fruit.

Many cranberry growers believe that frequent flooding to prevent injury from early frosts in the fall seriously affects the keeping quality of the fruit, although this is not uniformly the case. The writers had under observation one bog which during the fall of 1917 was completely submerged on 12 nights, and the fruit still showed exceptional keeping quality.

If the water is held for a considerable period continuously, however, the result is very likely to be disastrous. Cranberries of the Early Black variety on the Massachusetts State bog, which had been submerged for two weeks after the bulk of the crop was harvested, showed a great increase in the rot of the flooded fruit as compared with the fruit harvested before the flooding. In this case, indeed, a serious infection of *Sporonema oxycocci* (ripe-rot) occurred on the berries which had been submerged. Only a few of the berries picked before this flooding were found to be infected with this fungus. In northern cranberry regions during cold periods bogs are sometimes flooded and the water held so long that the fruit may be actually smothered. This practice is certain to injure the fruit.

The holding of winter flowage until mid-July, thus sacrificing one season's crop, is occasionally practiced in both Massachusetts and New Jersey as a means of reducing pests; this is one of the treatments recommended by Franklin (4) and by Scammell (7) for the reduction of several destructive insects. During the year following this treatment a large crop of berries of excellent keeping quality is said to be obtained, and the benefits, both in the reduction of field rot and in the improvement of keeping quality, are frequently said to persist for several years.

Spraying.

Thorough spraying has been found in all localities to reduce rot and improve the keeping quality of the fruit. In New Jersey and on Long Island, where there is always considerable loss from fungous disease before picking and where spraying has been practiced in some cases for 10 years, thorough spraying has been found profitable and no injury to the vines has been observed.

Experiments were conducted with the Early Black variety at Whitesbog, N. J., during 1917 to determine the times at which Bordeaux mixture should be applied in order to control fungous diseases most effectively and economically. Blast, early-rot, and a storage rot, all due to *Guignardia vaccinii* Shear, were the principal causes of loss on this bog during the year. Bordeaux mixture of the formula 4-4-50, with about 1 pound of resin-fishoil soap, was used throughout the experiments.

A single thorough application of Bordeaux mixture after the blossom buds had begun to open increased the total yield by more than 10 per cent (from 173 to 192 bushels per acre) by controlling blossom blast. Two applications before blossoming were no more effective than one. An application immediately before the spring reflow showed no effect in the control of fungi. No trace of the spray was observed on the vines when the water was removed. The applications before blossoming had no effect in reducing the rotting of the fruit after picking.

Protection of the berries from infection during the first month of their growth resulted in very satisfactory control of both field and storage rots. This was accomplished by two thorough applications, one near the close of the blossoming period (before all the petals had fallen) and another two weeks later. By these applications alone the total yield was increased, the rot at picking time was reduced from more than 20 per cent to less than 2 per cent, and storage rot from 6.7 per cent to 1.9 per cent. These two sprays applied at the proper time effected a saving of 44 bushels of marketable cranberries per acre, or one-fourth of the crop. Any delay in making the first application after blossoming resulted in a marked increase in both field rot and storage rot.

A third application after blossoming was of no increased benefit in these experiments. It must be repeated, however, that early-rot was the only fungous trouble of importance on this bog; furthermore, the berries were picked before the middle of September. It is doubtful whether two applications after blossoming will give satisfactory control with all varieties or where other diseases, such as bitter-rot, are concerned. A similar series of experiments with cranberries of the Centennial variety in New Jersey during 1917 gave unsatisfactory

and unreliable results because of severe frost injury. Further experiments along this line are necessary and are in prospect.

The use of Bordeaux mixture with resin-fishoil soap, which has been found to be the most effective fungicide for cranberries, is recommended. One application should be made just after the blossoms begin to open and should be repeated every two weeks until August 15.

In Massachusetts small plats of berries on the State bog which were sprayed with Bordeaux mixture for several years in succession have shown some injury to the vines. More experiments are necessary in order to determine the cause of this injury. As no injury of this kind has been observed in New Jersey or on Long Island, the writers feel that where losses from rot either before or after picking are heavy the benefit from spraying will more than offset any probable injury.

Dry Picking.

Experiments conducted on a number of bogs in New England have indicated that cranberries should be picked dry. The results shown in Table III are summarized from tests made in 1917. In each case from 4 to 10 bushels of berries were picked early in the morning while still wet with dew and an equal quantity taken from an adjacent portion of the bog as soon as the berries were thoroughly dry.

TABLE III.—*Comparative results of storing cranberries that were picked wet and dry in 1917.*

Variety.	Locality.	Days in storage.	Percentage of rotten cranberries.	
			Picked dry.	Picked wet.
Early Black.....	East Wareham, Mass.....	56	32	51
Howe.....	do.....	44	13	40
Early Black.....	South Wareham, Mass.....	24	a 17	a 20
Cherry.....	Madrid, Me.....	60	2.4	6.0

a Contained about 10 per cent of rotten berries when picked.

That the inferior keeping quality is due to the fact that the berries were wet and not to any injury received in picking is indicated by the fact that similar deterioration in keeping quality followed where boxes of berries which had been picked dry were wet with clean water.

During the latter part of the shipping season cranberries are sometimes removed from a cool storage house to a warm room for sorting and packing. If the humidity of the air is high, moisture frequently condenses on the berries to such an extent that they become wet and sticky. This is injurious to their keeping quality and should be carefully avoided. Cranberries should never be barreled or shipped in this condition. The desirability of packing and, if pos-

sible, sorting in cool rooms, which will prevent wetting the fruit by condensation from the air, is further considered under the next topic.

Low Temperature.

A study of the temperature relations of many of the fungi which cause fruit rots of cranberries (14, pp. 524 and 525) has shown that most of them grow very slowly, if at all, below 10° C. (50° F.). The only conspicuous exception is the end-rot fungus, which grows somewhat even at 0° C. (32° F.). The rate of growth of all these fungi, and consequently of the rot which they cause, increases rapidly with rise of temperature above 10° C. (50° F.). As already mentioned, the ripening processes which result in the death of the cranberry itself also go on more rapidly as temperature rises.

As an illustration of the effect of temperature on the keeping quality of cranberries, the results of temperature tests conducted at Washington, D. C., during 1916 and 1917 may be cited (Table IV). Equal quantities of apparently sound cranberries from uniform lots were kept at different temperatures in the refrigeration apparatus described by Brooks and Cooley (1).

TABLE IV.—*Effect of temperature on the keeping quality of cranberries as shown by tests made at Washington, D. C., in 1916 and 1917.*

Variety.	Days in storage.	Percentage of cranberries spoiled in storage at temperatures— ¹				
		0° C. (32° F.).	5° C. (41° F.).	10° C. (50° F.).	15° C. (59° F.).	20° C. (68° F.).
Early Black.....	28	2	4	5	12	19
Do.....	28	1	1.5	3.5	9	13
Howe.....	25	2.5	5	8	15.5	19
Early Black.....	60	16	27	.....	48	72
Do.....	60	20	27	.....	51	66
Do.....	56	39	43	.....	92	99
Howe.....	67	8	27	.....	48	76

¹ This includes smothering and all forms of fungous rot.

In the course of the first three tests, the results of which are given in Table IV, it was observed that cranberries color more rapidly at relatively low temperatures (5° C., 41° F.). It is, then, desirable from every point of view for cranberries to be kept as cool as practicable.

When cranberries are picked they are usually at a temperature considerably warmer than that of the air, and the sooner they are cooled the better. To this end it is desirable that cranberries should be removed from the bog as soon as practicable and placed in the shade. They should be stored in ventilated boxes, never in barrels, and the boxes should be so piled as to permit free circulation of air among the boxes.

The storehouse in which cranberries are held should be kept as cool as is possible without danger of freezing the fruit. This can be done most economically by having the house provided with adequate ventilators to admit air at the bottom of the building. These

ventilators should be open during cool weather and closed when the temperature of the outside air rises above that of the storehouse.

As already stated, cranberries which are held in the chaff and shipped during cold weather are frequently brought from a cold to a warm room for sorting. In order that sorters may work comfortably and efficiently the room in which the work is done must be at a temperature of at least 15° C. (60° F.), while the fruit in storage is often at a much lower temperature. If cool cranberries are held in a warmer room long enough for proper screening, their temperature is considerably raised, and if they are barreled in this room the higher temperature may be maintained long enough to affect their keeping quality seriously. As an instance of the injury to keeping quality which may result from such treatment, a test made in the fall of 1916 may be cited. Equal quantities of Early Black cranberries were taken from a barrel which had been kept for some time at a temperature of 7° to 10° C. (45° to 50° F.). One portion was taken to a warm room, about 24° C. (75° F.), and carefully hand sorted, the process taking in all about 40 minutes, after which the sound berries were returned to the original temperature. An equal portion was sorted in the cool room. At the end of 10 days the two lots were again sorted, with the results shown in Table V.

TABLE V.—*Comparative results of sorting cranberries in warm and in cool rooms, in the autumn of 1916.*

Treatment.	Number of berries.	Berries rotten 10 days after sorting.	
		Number.	Per cent.
Sorted in a warm room.....	973	153	17
Sorted in a cool room.....	968	88	

To avoid loss from this source and from wetting the fruit by condensation from the air, berries should not be sorted in a heated room unless necessary. When weather conditions make this imperative they should be removed from the warm room as soon as possible and should not be packed in the sorting room. Packing in a warm room means including in the barrel a quantity of warm air, which in a tight package retains its heat for a considerable time.

Perhaps the most efficient means of overcoming this difficulty is one that can be readily arranged where sorting belts are used. This method is used by at least two growers, one in Massachusetts and the other in New Jersey. The separators and packers are in a large room which is kept at the temperature of the fruit, while the belts carrying the fruit to be sorted pass through a smaller inside room which

is kept at a higher temperature and in which the sorters work. With such a system, using belts 30 feet long, no berry is exposed to warm air for more than 1 minute and the air in which the berries are packed is as cool as that in which they were stored. Careful temperature tests made in such a sorting house in Massachusetts showed that with the temperature of the berries at 7° C. (45° F.) and that of the sorting room at 18° C. (65° F.), the temperature of the berries was raised not more than 1 degree centigrade in sorting.

Ventilation.

Adequate ventilation of the cranberry storehouse is necessary first of all as a means of lowering the temperature of the fruit as soon as possible after it is picked. Its importance is not by any means confined to the effect on temperature, however, for, as pointed out earlier, improper ventilation results in smothering and sometimes in increased decay. In order to obtain the best results, cranberries should be stored in ventilated boxes which are so piled as to permit a free circulation of air among the berries.

The same principle may well be extended to the packages in which cranberries are shipped, particularly for the early shipments, which are frequently made during very warm weather. In this connection, the writers carried on experiments during both 1916 and 1917, in which berries were shipped in containers of different types. The results of these experiments are summarized in Table VI. In general it may be stated that the fruit in the smaller, well-ventilated containers kept better than that in the barrels. Of these containers the ventilated half-barrel box is perhaps the most satisfactory.

Ventilated barrels in which there are from 28 to 32 small openings (every other stave having two notches in each side) offer a convenient substitute for the tight barrel and one which may be introduced at slight expense and without the delay and effort incident to introducing a new package to the trade. Such barrels are now in use for early shipments by at least one large grower. While the writers have as yet been unable to carry out satisfactory comparative tests of ventilated and tight barrels, in a simple shipment of Early Black cranberries from Massachusetts the berries in the ventilated barrels appeared drier than those in the tight barrels. It is hoped that next season it will be possible to make shipping tests of a size sufficient to settle the question as to the amount of advantage derived from using ventilated barrels.

TABLE VI.—*Shipping tests of cranberries in different types of containers during 1916 and 1917.*

Variety.	Year.	Point of shipment.	Point of receipt and examination.	Percentage of spoilage.	
				In tight barrel.	In ventilated crate.
Early Black.....	1916	East Wareham, Mass..	Washington, D. C.....	38	29
Do.....	1916	South Wareham, Mass..	Livermore Falls, Me..	23	16
Howe.....	1916	East Wareham, Mass..	Washington, D. C.....	21	11
Do.....	1917	do.....	Chicago.....	22	a 18
Do.....	917	Wareham, Mass.....	New York.....	13	9

a Ventilated half-barrel box.

In this connection it may be noted that cranberries color better in well-ventilated containers.

Careful Handling.**DECAY INCREASED BY BRUISING.**

Bruises caused in harvesting, separating, or sorting cranberries form, as already stated, an important cause of increased decay. This was strikingly shown by a test made at Whitesbog, N. J., in 1916, using Centennial cranberries immediately after harvesting, before they had been separated or sorted. Each berry in a 10-pound sample was examined critically for the presence of scratches, bruises, or other blemishes which were so slight as not to be noticed in a casual inspection or picked out by the most careful sorter. Nearly one-fourth of the berries were found to be so injured; all of them were marketable and, to the inspector, apparently sound; they showed no signs of fungous decay. The injured and uninjured berries were placed in separate ventilated corrugated paper boxes and left in the storage house for two months. At the end of that time they were reexamined and the results noted, as shown in Table VII.

TABLE VII.—*Relation of slight injuries to the keeping quality of cranberries, as shown by a test made at Whitesbog, N. J., in 1916.*

Condition before storage.	Number of berries.	Rotten after being stored two months.	
		Number.	Per cent.
Sound.....	2, 171	97	4.5
Slightly injured, but marketable.....	697	316	45.3

Table VII shows that after two months in storage there was ten times as much rot among the previously bruised berries as in the sound ones. Many of these unnoticed injuries occur in each process of handling the fruit. This emphasizes the need of care and of

improvement when possible in methods of harvesting, separating, sorting, and packing cranberries.

HARVESTING.

Careful experiments in which the keeping quality of hand-picked cranberries was compared with that of scooped berries have not shown any very decided advantage in favor of either method, provided the scoopers were not allowed to pick up dropped berries from the ground.

A series of tests in New Jersey in the fall of 1916 showed that the keeping quality of these dropped berries was much inferior to that of berries picked or scooped from the vines. The results of these tests are summarized in Table VIII. The experiment with Early Black cranberries was conducted by Mr. Franklin S. Chambers. Adjacent similar plats of each variety were marked on the bog; then the berries from half the plats were picked by hand by experienced pickers and the remainder harvested by experienced scoopers. All berries were stored for two months in ventilated 1-bushel boxes in adjacent piles in a ventilated storage house.

TABLE VIII.—*Effect of different methods of harvesting upon the keeping quality of cranberries, as shown by tests made in New Jersey in 1916.*

Variety.	Method of harvesting.	Total weight (pounds).	Condition noted (per cent).			
			Immediately after harvesting.		Rotten after being stored 2 months.	Rot developed in storage.
			Slightly bruised.	Rotten.		
Early Black.....	Picked.....	1,168	(¹)	(¹)	12	.....
Do.....	Scooped.....	1,054	(¹)	(¹)	14	.....
Centennial.....	Picked.....	171	12	6	17	11
Do.....	Scooped.....	164	18	5	12	7
Do.....	Picked up after scoopers..	38	34	6	25	19
Howe.....	Picked.....	425	.....	—1	4.5	3.5
Do.....	Scooped.....	384	.....	—1	4.2	3.2
Do.....	Picked up after scoopers..	41	.....	—1	18.1	17.7

¹ Not determined.

Berries picked up from the ground after scooping, as Table VIII shows, bore a much higher percentage of the slight injuries mentioned above than did any of the other fruit, and, as was to be expected, this was the cause of their poor keeping quality. It seems from this evidence that if dropped fruit is picked up from the ground it should be kept separate, in order not to lower the grade or keeping quality of all the berries.

It is probable that neither method of harvesting can be said to be best under all conditions, but that factors other than keeping quality, such as length and uniformity of pine growth, will influence or determine the method to be preferred in any particular locality.

SEPARATING AND SORTING.

Very important and difficult to eliminate are the numerous unnoticed injuries caused in the processes of separating, sorting, and packing the fruit. Franklin (4, p. 21) has published data which show that the bruising caused by running berries through the separator and by dropping them into a barrel markedly increases the amount of rot. The results of the investigation of the writers fully substantiate these conclusions. Great injury is also caused by squeezing the berries in sorting. In this process the decayed berries are often detected by touch even more than by sight, and much sound fruit is thus squeezed or pressed unnecessarily. The resulting bruises, while imperceptible, frequently serve to start decay.

An illustration of the relation of bruises received in separating and sorting to the development of decay in storage is found in the results of a test made at Whitesbog, N. J., in the fall of 1917, in which 75 bushels of Early Black cranberries were picked on September 14 from plats which had been thoroughly sprayed during the summer. On September 21 the berries from each plat were divided into three representative parts. One part was then set aside in the storage house without further handling. The second part was sorted by hand on stationary sorting tables by commercial sorters, the percentage of unsound fruit noted, and the sound berries placed in the storage house. The berries remaining were then separated by machine and finally by hand in the usual commercial manner, the percentage of unsound fruit noted, and the apparently sound berries placed in storage. In this last method practically all unsound berries were removed by the machines, and the berries therefore suffered very little by handling during the final process of hand sorting.

All the berries were stored for nearly six weeks in ventilated storage boxes of 1-bushel capacity in a house in which the temperature varied from 15° C. to 7° C. during the season. For purposes of further comparison, 32 bushels of the Early Black variety that were picked on the same day (Sept. 14) from unsprayed plats on the same bog were divided, handled, and stored at the same time and in the same manner as those from the sprayed plats. Berries of good keeping quality (sprayed) were thus compared with those of poor keeping quality (unsprayed) as to the effect upon them of separating or sorting before storage.

On October 31 all the berries were removed from storage, sorted by commercial sorters, and the percentage of unsound fruit noted. The results are summarized in Table IX.

TABLE IX.—*Increase in amount of rot due to separating or sorting cranberries, as shown by tests made at Whitesbog, N. J., in 1917.*

Conditions of test.	Results noted (per cent).			
	Rotten Sept. 21 (1 week after picking).	Total rotten on Oct. 31 (after 6 weeks in storage).	Rot developed in storage.	Increase of storage rot due to previous handling.
Berries of good keeping quality (sprayed):				
Hand sorted before storage.....	1.6	5.9	4.2	1.9
Separated and sorted before storage.....		5.7	4.1	1.8
Not handled before storage.....		3.9	2.3	.....
Berries of poor keeping quality (unsprayed):				
Hand sorted before storage.....	21.6	30.4	8.8	7.8
Separated and sorted before storage.....		28.3	6.7	5.7
Not handled before storage.....		22.6	1.0	.....

Table IX shows that even with berries of excellent keeping quality the amount of decay developed in storage was nearly doubled by a previous sorting either by hand or by machine and that the effect of hand sorting was at least as severe as that of machine separating. On berries of potentially poor keeping quality the effect was similar but very much more marked. It appears that these berries did not decay in storage any faster than the sprayed berries unless they had been bruised previously by sorting, but that when so bruised the rot developed rapidly and in large amount. Here, again, hand sorting alone proved slightly more injurious than separating by machine.

This experiment indicates that the berries should be handled as little as possible and as late as possible before disposal, especially in the case of fruit of bad or doubtful keeping quality.

As another example of the increase in the amount of decay which is caused by hand sorting, the results of a test made at Wareham, Mass., in the fall of 1917 may be cited. Ten bushel boxes of Early Black cranberries were scooped on September 12 in such a way that two boxes came from each of five different regions of the bog, the two boxes from each region being as nearly alike as possible. All the berries were stored with abundant ventilation at a temperature which varied from 15° to 5° C. (59° to 41° F.) as the season advanced. Five boxes, one of each pair, were carefully hand sorted on October 3 and the good berries replaced in the boxes and held until November 6, when all the berries were sorted. The results, summarized in Table X, indicate that the sorting on October 3 more than doubled the amount of rot during the following month.

TABLE X.—*Increase in rot due to the sorting of cranberries, as shown by a test made at Wareham, Mass., in 1917.*

Treatment.	Condition noted (per cent).		
	Rotten on Oct. 3.	Rotten on Nov. 6.	Total rot.
Sorted once during storage.....	4.3	15.8	20.1
Not sorted during storage.....		11.0	11.0

To avoid such losses as have been cited, all berries, especially those of doubtful keeping quality, should be handled as little as possible, they should be cleaned as near the time of shipping as possible, and in sorting care should be exercised not to touch or bruise the berries unnecessarily. It is possible that separating machines may be devised which will injure the fruit less than those at present in use. Improvement can certainly be made in the methods of hand sorting. The most thorough sorting is not necessarily the best if it is accompanied by too much handling of the berries. Sorting belts in which the berries pass from the separator over a slowly moving belt which carries them in front of the sorters and deposits those not removed in a box or barrel at the end have the advantage of making it unnecessary for sorters to handle the fruit roughly, provided there is some device for turning the berries on the belt. An easer¹ of some kind should be used to prevent bruising when berries drop into a barrel or other container.

SHIPPING IN THE CHAFF.

When berries come from the bog they have more or less leaves, broken vines, or other foreign matter mixed with them. Fruit in this condition is said to be "in the chaff."

As a result of the knowledge of the fact that the processes of cleaning cranberries increase their tendency to decay and that it is advantageous to place them before the consumer as soon as possible after cleaning, some growers have attempted shipping berries in the chaff and having them cleaned at destination. For berries particularly subject to decay after sorting this plan is apparently to be recommended.

The writers have had the opportunity to test this method in only one instance, a shipment of berries from a bog in Wareham, Mass., to Chicago, Ill. Two varieties were used in the experiment, and equal quantities of berries as uniform as could be secured were chosen. Half of each lot was carefully separated and sorted before shipment and the shrinkage noted; the other half was shipped in the chaff. At destination all lots were run through a separator and the shrinkage again noted. The berries were packed in Wareham on

¹ Easer is a term the writers apply to any device for breaking the fall to prevent bruising.

October 26 and examined in Chicago on November 15, 1917. The results are given in Table XI.

TABLE XI.—*Comparative results of shipping cranberries before and after cleaning, as shown by tests made in 1917.*

Variety.	Condition when shipped.	Shrinkage noted (per cent).		
		In first cleaning.	In separating at Chicago.	Total.
McFarlin ¹	In chaff.....	.....	23.7	23.7
Do.....	Separated and sorted.....	20	10.2	30.2
Middleboro.....	In chaff.....	.....	27.0	27.0
Do.....	Separated and sorted.....	20	15.5	35.5

¹ Contained more than 10 per cent of frozen berries.

It will be noted that with both varieties the total loss of berries was greater with those cleaned before than with those cleaned after shipment. This is particularly marked in the case of the Middleboro variety, which contained no frosted berries and therefore gave a more accurate test.

Shipping in the chaff naturally involves the extra expense of freight charges and containers for the chaff and decayed berries which would be taken out in cleaning. On the other hand, if fruit is shipped in the chaff it may be held in storage and run through a separator as sold. Under these conditions hand sorting will not be necessary and the cost of preparing for sale is materially reduced. In deciding whether to attempt shipping in the chaff each grower will have to take into consideration his own expense of separating and sorting, the probable keeping quality of his berries, and whether the consignee has adequate facilities for separating the fruit. Shipping in the chaff will then be confined to consignments to large dealers and will be most profitable in the case of fancy fruit of relatively poor keeping quality.

SUMMARY.

Recent observations and investigations have shown that about 15 per cent of the cranberry crop is lost between the field and the consumer. The losses are due in part to fungous rots and in part to smothering.

Bruising of the fruit occurs in the operations of picking, separating, sorting, and packing. Such injury is not only a direct cause of spoilage, but renders the fruit much more liable to decay. Much more rot has been found in roughly handled or bruised fruit than in carefully handled fruit.

No direct relation has been found between the humidity of the air in which the fruit is kept and the amount of rot which develops. Death and spoilage of cranberries will finally result from natural ripening of the fruit. This process is hastened by high temperatures and reduced by low temperatures.

Cranberries kept in tight packages which do not permit ventilation soon die from smothering and are of little value for food. Such fruit is soft and the tissues are discolored. Spoilage by smothering may be caused by keeping the berries in large piles, by having them too closely crowded in unventilated storerooms, or by flooding for too long a period, especially in warm weather.

Extended investigations indicate that at least one-half of the spoilage of cranberries after picking is due to fungous rots. These vary much in prevalence and destructiveness in different seasons and localities, depending upon a variety of factors.

The chief rots which develop after picking are early-rot, caused by *Guignardia vaccinii*; end-rot, caused by *Fusicoccum putrefaciens*; bitter-rot, caused by *Glomerella cingulata vaccinii*; ripe-rot, caused by *Sporonema oxycocci*; blotch-rot, caused by *Acanthorhynchus vaccinii*; and soft-rot caused by species of *Penicillium*. The fungous rots which develop after picking, as well as before, may be largely prevented by spraying with Bordeaux mixture to reduce infection. Improved bog management also increases the vigor of the vines and tends to reduce rot.

Cranberries picked and stored or packed wet show more rot than those picked and packed dry; when cooled as soon as practicable after picking and kept at low temperatures they show a great reduction in the amount of rot. The most favorable temperature for keeping berries is 32° F. Temperatures above 50° F. produced rapid increase in the development of rots. Berries warmed by being kept in a heated room while being sorted showed an increase in the amount of rot.

Ventilated barrels or other ventilated packages used in distribution gave less rot and other spoilage than tight packages.

A comparison of different methods of harvesting the fruit showed but slight differences in its keeping quality.

A study of the effect of separating fruit by machines and by hand sorting showed but little difference in the result. All lots developed much more rot than the check. The results indicate that separating and sorting should be delayed until the fruit is to be shipped.

Cranberries shipped in the chaff, that is, without cleaning or sorting, and separated and sorted at destination, showed less loss from rot than those separated and sorted before shipment.

PRACTICAL SUGGESTIONS.

Spray thoroughly to prevent fungous infection.

Pick and handle the fruit with great care to avoid bruising.

Cool the berries as quickly as possible after picking and keep them cool until they are shipped.

Store and handle the fruit in a cool, well-ventilated building, and use ventilated packages, especially for early shipments.

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 715

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E. W. NELSON, Chief.



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ATTRACTING BIRDS TO PUBLIC AND SEMIPUBLIC RESERVATIONS.

By W. L. McATEE, *Assistant Biologist.*

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The popular motive for attracting birds is esthetic enjoyment. The sprightly activity of birds, their beauty of form and color, and their interesting and often charming notes have a wide appeal. Thousands of persons, therefore, have taken steps to increase the number of birds upon their own property.¹ While less has been done by concerted public effort, still a beginning has been made. Any campaign of this kind must take into account the economic as well as the esthetic results of bird attraction and protection. Birds are beneficial as enemies of a great variety of pests, and it is claimed by several observers that an abundance of birds on their grounds has kept in subjection all the ordinary enemies of trees, shrubbery, and herbage. At all events, birds exert a steady influence in reducing the numbers of injurious plant feeders and should be particularly useful in public reservations, where beauty and utility so largely depend upon preserving the vegetation.

¹ Information on attracting birds is contained in the following Farmers' Bulletins: 621, relating to the Northeastern States; 760, to the Northwestern States; 844, to the Middle Atlantic States; and 912, to the East Central States.

NOTE.—For general distribution among organizations and individuals interested in the protection of wild birds. Of especial value to those in charge of parks, cemeteries, and other public and semipublic reservations.

The classes of public reservations upon which more attention might well be paid to attracting birds include the national parks, monuments, and forests; national bird reservations and game refuges; and State and municipal parks, including, when spacious enough, those surrounding public buildings, botanical and zoological gardens, the environs of reservoirs and waterworks, and parkways, boulevards, and roadsides.

Among semipublic reservations upon which bird-attraction methods could be profitably applied are the grounds of colleges and other schools, cemeteries, fair grounds, and the right of ways and other parked areas of transportation lines.

NATIONAL RESERVATIONS.

The Federal Government has wisely set aside various tracts of public land, either to preserve areas of great scenic or ethnologic interest, or to assist in the perpetuation of such natural resources as forests, game animals, and birds. The primary purpose of these reservations, to preserve objects of great interest, may well be supplemented by an attempt to increase within safe limits their natural attractions, among which are birds.

On the national parks and monuments, which are great public recreation grounds, birds may well be increased, because of their strong appeal to many tourists. In the Yosemite National Park much has already been done in the way of erecting bird houses and planting fruit-bearing shrubs, especially near the main thoroughfares. The methods that may be followed are those described in the Farmers' Bulletins cited in the footnote on page 1, and in No. 609, entitled Bird Houses and How to Build Them.

The objects of the national forests are primarily utilitarian, and they will certainly be furthered by an increase in the number of birds. Great efforts are now directed toward reducing rodent pests in national forests, as a measure of protection not only to the forests, but also to crops on adjoining lands. Upon the same principle, an increase in useful birds within the forests will have a beneficial influence throughout the environs of these reservations. The methods recommended for this purpose are those mentioned in the preceding paragraph.

On the national bird reservations and game refuges, which have been established for the precise purpose of preserving and increasing wild life, the use of bird-attraction methods should be an essential part of the administration. To make these places more attractive to birds in general and to benefit the smaller birds directly, the measures already referred to should be used. The problem of better fitting the reservations for other birds may be treated as dual, involv-

ing catering to, and thus increasing the numbers of, waterfowl, and, with the same objects in view, improving suitable ranges for upland game birds.¹

ATTRACTING WATERFOWL.

The chief attraction for our most important waterfowl, the ducks and geese, is a copious supply of food, furnished by aquatic and semi-aquatic plants. Since these plants are the basic source of food of small animals, as insects, crustaceans, and fishes, upon which ducks and geese as well as other waterfowl feed, it is evident that increasing the vegetable food resources of wild ducks and geese also improves living conditions for all the other feathered inhabitants of marshes and lakes.

The vegetable food of wild fowl is derived from a great variety of plants. An important part of it consists of the tubers, seeds, and foliage of submerged water plants of the groups of pondweeds, musk grasses, wild celery, widgeon-grass, coontail, and milfoils. The plants which at least in part float upon the surface, including the waterlilies, duckweeds, water primroses, water pennyworts, and frogbit, also supply much wild-duck food. Semisubmerged plants of value comprise a long series of bur-reeds, arrowheads, smartweeds, and other plants, as thalia, pickerel weed, and watercress, together with all the marsh grasses and sedges, among which are some of the most important species, as wild rice, wild millet, cord and switch grasses, meadow grass, and bulrushes. A similar and valuable duck-food plant suited to drier ground is chufa, but a large number of shore plants of entirely different character produce large quantities of food for waterfowl. These are mast and fruit-producing shrubs and trees which grow in shallows or on the margins of bodies of water. Among them may be especially mentioned buttonbush, water elm, water privet, swamp holly, cypress, hackberries, oaks, hickories, ashes, red haws, and grapes.

Cover plants which furnish concealment for nests, as well as for the birds themselves in time of need, are almost as important to wild fowl as food. Fortunately, many plants furnish both food and cover, the most valuable being the bulrushes and such marsh grasses as reed, salt, cord, and switch grasses.

Furnishing waterfowl resorts with as complete as possible an assortment of the plants named is certain to result in an increased number of birds frequenting them. Methods of propagating most of these species are described in two bulletins of the United States Department of Agriculture: No. 205, Eleven Important Wild-Duck Foods; and No. 465, Propagation of Wild-Duck Foods.

¹ Where local conditions warrant, these projects should receive attention also in national parks and forests.

IMPROVING COVERTS FOR UPLAND GAME BIRDS.

The favorite resorts of upland game fowl have long been known as coverts, no doubt on account of their being admirably adapted to covering or concealing the birds. Such coverts are usually characterized by an abundance of low but dense and stiff or thorny shrubbery, together with luxuriant growths of grasses and weeds. These plants supply also an important part of the food of grouse and quail; and adding goodly stocks of them to suitable areas in our national reservations will do much to preserve and increase the upland game.

Bob-whites frequently use coverts of rose, alder, and blackberry bushes, and also thickly set barberry and bayberry and dense banks

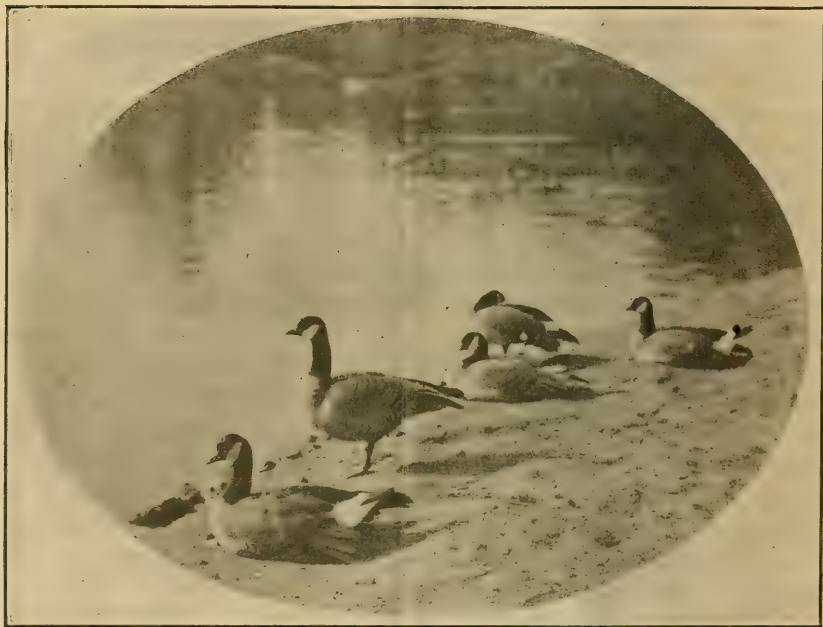


Fig. 1.—Wild geese in Golden Gate Park, San Francisco, Cal.

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of honeysuckle. These plants furnish food for the birds, but they should be supplemented by others more exclusively adapted for this purpose. Sumach, Japanese clover, buckwheat, sorghum, millet, vetches, cowpeas, and any plants of the pea family producing small seeds are valuable and should be sown in large quantities. The seeds of milk pea (*Galactia*), partridge pea (*Chamæchrista*), hog peanut (*Falcata*), wild bean (*Strophostyles*), and smartweeds (*Polygonum*) are important natural foods of the eastern quail, but should be encouraged only where they can not become weed pests. Western quail are fond of the seeds of sumach, bur clover, alfalfa, lupines, napa thistle, and turkey mullein plants; but where these

plants are liable to become nuisances the food plants recommended for the eastern quail will serve.

Coverts for grouse, as the sharp-tailed, should abound in such plants as rose, sumach, blueberry, bearberry, buffaloberry, dwarf birch, and alder. The ruffed grouse thrives among scrub oak, bayberry, rose, sumach, dwarf birch, alder, poplar, willow, and such fruit-bearing plants as partridge berry, hawthorn, viburnum, wild grapes, mountain ash, blueberry, blackberry, and cranberry. Cover of this nature is suited to the heath hen also and to the imported pheasants and the Hungarian partridge, but in all cases it is well to supplement the food supply furnished by these shrubs and trees by planting small grains and legumes as recommended for quail.

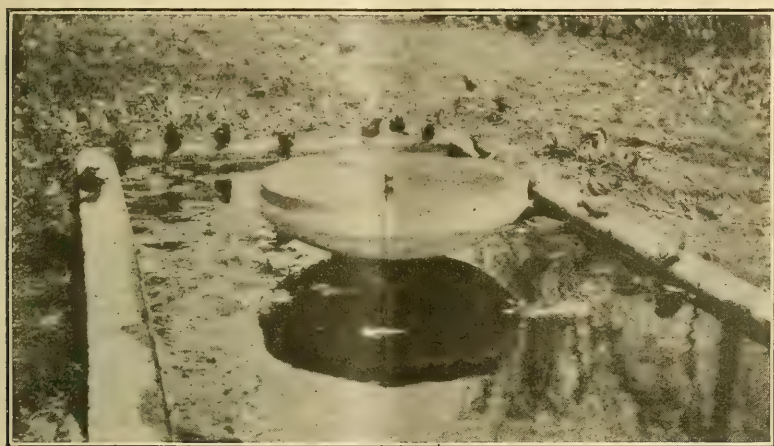


Fig. 2.—Cedar waxwings at a bird fountain.

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STATE, MUNICIPAL, AND OTHER PARKS.

Parks adorn public places and educate and recreate the people. They may be improved for all these purposes by increasing their bird population. Moreover, the alterations that need be made to improve a park as a bird haven may, and should, themselves be made to add to its attractiveness. For instance, water is used to enhance the beauty of most parks, and a water supply is one of the most potent attractions for birds (fig. 1). Bird baths (figs. 2 and 3) or fountains may take the form of small displays of water, which may be added to many parks without being obtrusive or conflicting with the general design.

An artistic martin-house well placed in one of the small open lawns that most large parks contain (fig. 4), would not only increase the beauty and interest of the place, but would add to its dignity by suggesting a specific usefulness for the space. As for nest boxes

for other birds, they may be so inconspicuously placed that the chief evidence of their presence would be the increased number of birds, and decreased injury to vegetation by insect pests. The perfection of specimen trees in parks and the work of the tree surgeon on imperfect trees make it necessary to supply nest boxes if the hole-nesting birds are to have any chance of inhabiting parks.

Feeding stations for birds are made in a number of slightly designs, and the principles upon which they are built allow of their being extensively varied or incorporated into other park structures. The greatest usefulness of feeding stations in parks, aside from the preservation of birds, is in rendering the parks more attractive to the public in winter. The feeding of birds is carried on with most obvious results



Fig. 3.—Flicker at a bird fountain.

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during the colder months, and adding this feature to parks appeals strongly to thousands of lovers of nature.

By means of feeding stations it is possible to attract to convenient observation points several species of the most interesting and valuable birds. Such stations are particularly pleasing to children. As evidence of the value of the method, the following statement of experience by Theodore Wirth, Superintendent of Parks, Minneapolis, Minn., is presented:

For the past five or six years we have maintained a number of feeding stations in various parts of our park system, with very satisfactory results. I give you a list of the birds which stay with us over winter. The permanent winter-birds found in the vicinity of our parks are the chickadee, blue jay, white-breasted nuthatch, downy and hairy woodpeckers, and screech owl; winter visitors, the redpoll, tree sparrow, and junco; irregular winter visitors, the evening grosbeak, Bohemian waxwing, and snow bunting. It is safe to say that a large number of these species are staying in the parks on account of the food supplied them. The feeding of the wild birds in the parks is a great success and will be continued.

Supplying water, nest boxes, and winter food goes far toward making a bird haven, but it is important also to supplement the summer food. This can best be done by planting fruit-bearing shrubs and trees. Shrubs and trees are essential elements of park composition, but according to the judgment of bird lovers better choice than is often made is distinctly possible.

The guiding principle in park planning should be beauty, but it should not be a temporary or one-seasonal beauty. Hence it follows that shrubs and trees which produce colored fruits, and retain them for long periods, are preferable to plants whose chief decorative contribution is a short burst of bloom. Such shrubs are handsomer at all times after flowering and are particularly valuable in winter



Fig. 4.—Martin house in parklike surroundings.

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when every bit of color in the landscape is precious. They are valuable moreover in supplying bird food. The kinds preferred by birds are shown in Table I (p. 8), and the species most suitable for various sections of the country are listed in the Farmers' Bulletins mentioned in the footnote on page 1.

A few further suggestions as to the use of fruit-producing plants are not out of place. The ideal American park is natural woodland, modified and embellished, or a planting that follows natural lines. Informal treatment is almost universally preferred to formal. From the standpoint of bird attraction this is fortunate, since clipping shrubs either prevents or reduces the production of fruit and causes the plants to form such solid and dense surfaces that they are uninviting to birds.

TABLE I.—*Preferences of birds among genera of fleshy fruits.*

Common name.	Scientific name.	Number of species of birds known to eat the fruit. ¹	Common name.	Scientific name.	Number of species of birds known to eat the fruit. ¹
Juniper; red cedar.....	<i>Juniperus</i>	36	Pepperberry.....	<i>Schinus</i>	10
Greenbrier.....	<i>Smilax</i>	38	Holly.....	<i>Ilex</i>	38
Bayberry.....	<i>Myrica</i>	64	Supple-jack.....	<i>Berchemia</i>	12
Hackberry.....	<i>Celtis</i>	38	Buckthorn.....	<i>Rhamnus</i>	16
Mulberry.....	<i>Morus</i>	52	Grape.....	<i>Vitis</i>	71
Pokeberry.....	<i>Phytolacca</i>	48	Virginia creeper.....	<i>Parthenocissus</i> ...	39
Barberry.....	<i>Berberis</i>	10	Buffaloberry.....	<i>Shepherdia</i>	13
Spicebush.....	<i>Benzoin</i>	17	Wild sarsaparilla.....	<i>Aralia</i>	14
Sassafras.....	<i>Sassafras</i>	15	Dogwood.....	<i>Cornus</i>	79
Currant; gooseberry.....	<i>Ribes</i>	30	Sour gum.....	<i>Nyssa</i>	36
Strawberry.....	<i>Fragaria</i>	42	Bearberry.....	<i>Arctostaphylos</i> ...	12
Raspberry; blackberry.....	<i>Rubus</i>	114	Huckleberry.....	<i>Gaylussacia</i>	30
Rose.....	<i>Rosa</i>	17	Blueberry.....	<i>Vaccinium</i>	62
Mountain ash.....	<i>Sorbus</i>	14	Mexican mulberry.....	<i>Callicarpa</i>	10
Chokeberry.....	<i>Aronia</i>	13	Partridge berry.....	<i>Mitchella</i>	10
Red haw.....	<i>Crataegus</i>	30	Elder.....	<i>Sambucus</i>	101
Juneberry.....	<i>Aamelanchier</i>	38	Snowberry.....	<i>Symphoricarpos</i> ...	22
Cherry; plum.....	<i>Prunus</i>	66	Black haw.....	<i>Viburnum</i>	26
Sumac ²	<i>Rhus</i>	76	Honeysuckle.....	<i>Lonicera</i>	15

¹ When 10 or more.² Nonpoisonous species.

It may further be said in favor of untrimmed shrubbery that the normal form and beauty of the plants, together with the resultant play of light and motion, are preserved. With this treatment a park has naturalness and life; under formal treatment the suggestions are those of restraint and immobility.

ZOOLOGICAL GARDENS.

If bird-attracting devices are a desirable addition to the resources of ordinary parks, they are a positive necessity in zoological gardens. Is not an abundance of native birds, giving opportunity for observation under natural conditions, preferable to a display of the same species in cages? Whenever a species can thus be put on exhibition in the wild state, it should be done. Bird fountains, nest boxes, and feeding stations are the devices which make the achievement possible.

BOTANICAL GARDENS.

Bird attraction may well be cultivated also in botanical gardens. The presence of numerous birds will not only make the park more entertaining to visitors, but will also result in decreased trouble from injurious insects. When spacious, the grounds surrounding all kinds of public buildings are available for bird-attraction centers, and should receive similar treatment to parks. Fair grounds also may be mentioned here; much effort usually is made to beautify them, and part of it could well be in a form beneficial to birds.

PARKWAYS, BOULEVARDS, AND ROADSIDES.

There exists in most parts of the United States either a superstition, a conviction, or a legal requirement that roadsides be shorn of their vegetation at least once a year. The result is that most country roads are very uninviting in summer. Hot and gray with dust, the highway stretches away before the traveler, often without a single tree to break the monotony of the view or afford relief from the rays of the sun. This baldness is brought about chiefly by two causes: (1) Fear that the roadside will unduly increase weeds and insect and rodent pests, and (2) lack of public spirit.

Fortunately, we have in this country examples of well-kept parkways and boulevards which border cultivated lands. Their ample parking is grown to grass and embellished with herbaceous flowers, shrubs, and trees. Yet the farm lands they border are neither overwhelmed by weeds nor devastated by insects and rodents.

The question of roadsides propagating vast numbers of noxious weeds may be viewed in more than one light. For instance, the mowing of waysides for long series of years has not done away with the need of cultivating crops; indeed it can not, for cultivation is necessary for other reasons (as loosening, aeration, and water conservation) than the destruction of weeds. Furthermore, the amount of cultivation customarily given crops is sufficient to control all the weeds the land will grow, and this number is generally present despite the razing of roadside growths. On the other hand, the lack of verdure and shade and the general dreariness of roadsides make it very desirable that a different treatment of these most extensive public parkings be adopted. Placing vines upon fences and planting numerous shrubs and shade trees¹ along the way will not only render the roads more attractive but will tend to keep down the dust.

So far as the effect upon birds is concerned, there can be no doubt that suppression of roadside vegetation is a potent factor in restricting their numbers. The same can be said of fence rows, which to an ever increasing degree are made to occupy the minimum of space; farmers may gain a planting row about every field by the destruction of vegetation along fences, but they lose the services of the birds, their best allies in fighting insects. Shrubby fence rows are among the best harbors and nesting places of small birds, and it is certain that encouraging an abundance of birds to live on farms is a profitable policy. It is greatly to be desired, therefore, that more be done to beautify roadsides and fence rows, not only as a measure to contribute to the comfort and pleasure of man but also substantially to increase a great economic asset—the bird population of the country.

¹ In plantings of this nature, it will be well to omit the common barberry, which serves as an alternate host for wheat rust; and wild cherry, which is so favorable a nursery for tent caterpillars.

RESERVOIRS.

The grounds surrounding reservoirs of drinking water usually are well fenced and carefully guarded to minimize contamination. This results in freedom from disturbance, a boon so highly appreciated by birds that in itself it goes far toward making these places satisfactory bird havens. Such reservations can be greatly improved for this purpose, however, by the use of bird houses and proper planting, measures which will be in no way deleterious to the water supply, but which will greatly benefit the birds, and through them the vegetation of the reserve and adjacent country.

Reservoirs for other than drinking water usually can be sown to aquatic plants, thus making them attractive to many water birds. The character of the planting will depend on circumstances; if a marshy margin is permissible, the place may be made into an excellent resort for wild fowl. If only submerged plants are desired and as clean a growth as possible, sago pondweed may be planted. Broader-leaved plants furnish much greater surface for lodgment of silt and growth of algæ. The methods of propagating a variety of aquatic plants are described in Department Bulletins 205 and 465.

COLLEGE AND OTHER SCHOOL GROUNDS.

The campus, like the park, has suffered from formal landscape gardening. Wall-like hedges, closely cropped circles, or triangles of shrubs, and mathematically designed edgings, beds, and gardens have gone far toward robbing school grounds of merit in the eyes of man, and have almost spoiled them for birds.

All of the arguments made in connection with parks show also the desirability of taking birds into consideration in campus planning. There is in addition the very important objective of keeping up an important educational resource. There is hardly an advanced school in the country that does not offer one or more courses of bird study. The study of birds out-of-doors is essential to a good bird course, and this need should be kept in view by those in charge of college and school grounds. Sylvan campuses where formerly birds abounded have been so filled with buildings, so gardened and formalized, that birds are now scarce. If possible, some corner (preferably of original woodland, where that exists) should be allowed to run wild. Judicious addition of food-producing plants should be made there, and the campus in general improved for birds by allowing shrubs to make natural growths. Putting up nest boxes would make up for the hole-eliminating activities of the tree surgeon. Winter feeding would be very interesting and instructive to many students and could be carried on as part of the course of bird-study classes. Finally, the teacher of ornithology might well

have an advisory capacity in relation to the planning and treatment of the campus.

CEMETERIES.

Cemeteries have the reputation of being good places for birds. The reasons, one must infer, are seclusion, freedom from disturbance, and an abundance of trees and shrubs. The last-named factor is by no means least, nor on the other hand is it so perfect as not to be susceptible of improvement. Selection of shrubs and trees with the needs of birds in mind would not interfere with the general plan of a cemetery, but would make it a still better resort for birds.

Formal landscape gardening is more prevalent (perhaps excusably so) in cemeteries than in other public reservations, yet there are very beautiful cemeteries in which formal composition plays little part. Here, as everywhere, the informal or naturalistic planting is most favorable to birds. Nest boxes can be added without being obtrusive, and bird fountains may be made to harmonize with the surroundings or even to serve as memorials.

The movement to convert cemeteries into bird sanctuaries and to improve them for the purpose is already well under way and is being fostered by the National Association of Audubon Societies. A pioneer in this work, H. S. Mann, secretary of the Forest Lawn Cemetery Association of Omaha, Nebr., reports:

We have been very successful in attracting birds to Forest Lawn Cemetery. The cemetery contains 320 acres, all fenced, and is located north of the city limits of greater Omaha. It has an abundance of trees and shrubbery, about 250 acres of the half section being unimproved at this time. A creek runs through the southern portion of the cemetery and east and north of it are great stretches of wild lands.

Bird houses, feeding stations, and baths have been erected in the cemetery. Quantities of tangled underbrush and small fruit-bearing bushes and vines have been set out and preserved for the birds. With these attractions, free from annoyance of cats, hunters, and children at play, it is a paradise for birds.

Bird students visit the cemetery frequently, as a larger number and a greater variety of birds may be found within its sacred enclosures than anywhere else in this section of the country, excepting perhaps the great Fontenelle Forest Reserve of 400 acres on the Missouri River adjoining the city on the south.

RIGHT OF WAYS.

A number of railroad companies have already made considerable effort to beautify their right of ways and station grounds. In some places the roads are paralleled for many miles by hedges, and the land on either side of the tracks is covered by beautiful turf. About the stations, hedges, shrubbery, and flower beds are common. If this planting could be aimed in part, at least, toward attracting birds it would be very effective and great good would be done. If the clumps of shrubs were formed of kinds furnishing bird food (see Table I), if more of them were placed along the right of ways, if the

hedges were allowed to bear fruit, and if the fence poles or possibly even some of the telegraph poles bore bird houses, thousands of birds could live where very few do now.

The suggestions made are by no means without practical value to the right of way itself. For instance, supplying bird boxes is the best method of preventing damage to poles by woodpeckers, which come anyway under present conditions and make their own homes. Hedges or fences densely covered with vines would decrease, if not entirely obviate, expenditures for the movable snow fences now extensively used.

The project of increasing the number of birds along the right of ways should interest the agricultural development bureaus of railroads. The small birds that are most easily encouraged when shrubbery, nest boxes, and water supply are provided, are chiefly beneficial. Increasing their numbers would result in great destruction of insects on adjacent farms, a very practical bit of agricultural improvement.

CONCLUSIONS.

The use of bird-attraction methods on numerous public and semi-public reservations in the United States would result in a decided increase in the number of birds and in the usefulness of the reservations. Benefit would accrue not only to these areas but, through increased destruction of injurious insects, to all adjoining lands and the country at large. The lands are available, the methods are known, and the certainly useful results wait only upon the interest and support of the administrative authorities.

PUBLICATIONS OF THE U. S. DEPARTMENT OF AGRICULTURE RELATING TO THE PROTECTION AND ATTRACTION OF WILD BIRDS.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

Eleven Important Wild-Duck Foods. (Department Bulletin 205.)
Propagation of Wild-Duck Foods. (Department Bulletin 465.)
The Duck Sickness in Utah. (Department Bulletin 672.)
Bird Houses and How to Build Them. (Farmers' Bulletin 609.)
How to Attract Birds in Northeastern United States. (Farmers' Bulletin 621.)
How to Attract Birds in Northwestern United States. (Farmers' Bulletin 760.)
How to Attract Birds in the Middle Atlantic States. (Farmers' Bulletin 844.)
How to Attract Birds in the East Central States (Pennsylvania to 100th meridian). (Farmers' Bulletin 912.)
Game Laws for 1917. This publication contains the texts of the Federal migratory-bird law; the treaty of 1916 protecting birds migrating between the United States and Canada; the Canadian migratory-birds convention act; and other matters relating to the protection of birds. (Farmers' Bulletin 910.)
The Great Plains Waterfowl Breeding Grounds and Their Protection. (Separate 723, Yearbook 1917.)

FOR SALE BY THE SUPERINTENDENT OF DOCUMENTS, GOVERNMENT PRINTING OFFICE, WASHINGTON, D. C.

Preliminary Census of Birds of the United States. (Department Bulletin 187.) Price, 5 cents.
Mortality Among Waterfowl Around Great Salt Lake, Utah. (Department Bulletin 217.) Price, 5 cents.
Second Annual Report of Bird Counts in the United States, with Discussion of Results. (Department Bulletin 396.) Price, 5 cents.
Our Shorebirds and Their Future. (Separate 642, Yearbook 1914.) Price, 5 cents.
Plants Useful to Attract Birds and Protect Fruit. (Separate 504, Yearbook 1909.) Price, 5 cents.
Bird Day in the Schools. (Biological Survey Circular 17.) Price, 5 cents.
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 716

Office of the Secretary
Contribution from the Office of Farm Management
W. J. SPILLMAN, Chief



Washington, D. C.

PROFESSIONAL PAPER

September 26, 1918

A FIVE-YEAR FARM MANAGEMENT SURVEY IN PALMER TOWNSHIP, WASHINGTON COUNTY, OHIO, 1912-1916.

By H. W. HAWTHORNE, *Scientific Assistant.*

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GENERAL NATURE OF THE AREA AND THE STUDY.

This bulletin presents a study of a farm-management survey of 73 southeastern Ohio hill farms, on 25 of which the survey was conducted for five successive years, 1912 to 1916, inclusive.¹ All these farms are located in one township of Washington County. (See fig. 1.) In common with many other areas of the hill country drained by the Ohio River, the land here is fairly productive and comparatively low priced. The farms are some distance from railroad points, and the wagon roads are hilly and unimproved.

The findings for this area, though strictly applicable only to the farms surveyed, offer valuable suggestions to farmers located on the numerous similar areas of Pennsylvania, Ohio, Indiana, Illinois, West Virginia, and Kentucky.

OBJECTS OF THE STUDY.

The objects of this study were:

(1) To ascertain the type of farming followed and the profits realized in a long-established agricultural community of the hill

¹ During the first two years the survey was conducted in cooperation with the Ohio Agricultural Experiment Station. During the three succeeding years it was conducted by the Office of Farm Management alone.

country of Ohio where the price of land is comparatively low and railroad points are reached with considerable difficulty.

(2) To determine the importance of such factors as the size and the quality of the farm business as they affect the economic organization of farms in such an area.

(3) To bring out the farm practices that enable some farmers to excel others in single enterprises or in the entire farm organization.

(4) To determine how nearly the farm profits of a single year in such an area are indicative of those realized over a period of years.

(5) To note agricultural changes that may take place during a five-year period in such an area.

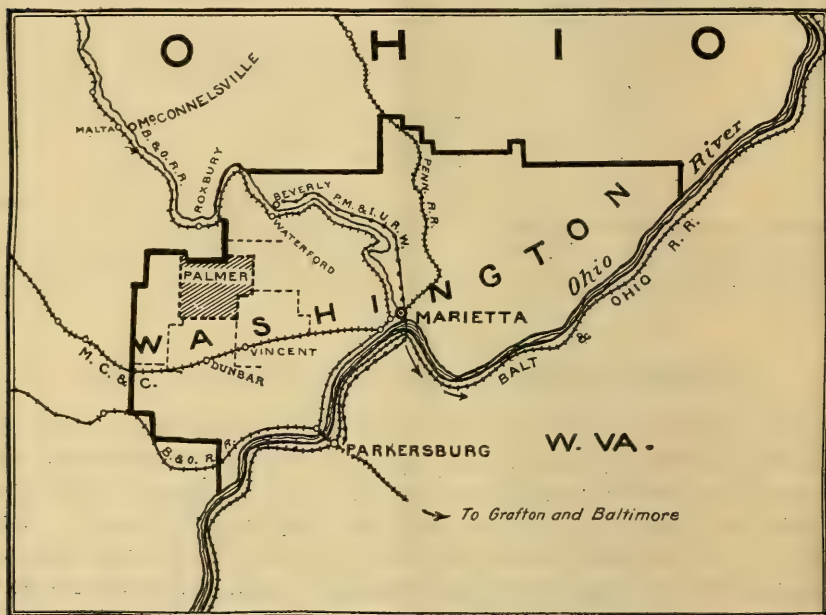


FIG. 1.—Map of Washington County, Ohio; Palmer Township shaded.

(6) To determine the yearly variations in crop yields, in prices received for products, in the quantities of the several products available for sale, and in the expenses of operating the farm business, and, so far as practicable, their effect upon the farm profits of the area.

SUMMARY OF RESULTS.

For five years the average annual sales of 25 farms were \$925 per farm, and of this amount 45 per cent was required for operating expenses. With a fair rate of interest allowed on the investment the labor income averaged \$187. Or, with a fair wage allowed for the farmer's labor, the return on the investment was 3.4 per cent. This was in addition to the value of food products, fuel, and use of house,

furnished by the farm without money cost. The value of such items was \$325.

The farms averaged 156 acres, worth \$30 per acre. One-half of the land was in pasture and one-fourth in corn, wheat, and hay. The crops were mostly fed to beef cattle, poultry, fine-wooled sheep, hogs, and work stock. Practically 75 per cent of the receipts was from the sales of live stock, including eggs, wool, and dairy products.

So far as profits were affected, one year was good, one poor, and three might be considered normal.

Profits varied widely. Some farmers made more than enough to support their families and were enabled to reduce indebtedness, improve their farms, buy more land, or make other investments. Others realized no more than enough to supply the necessities of life. The two outstanding factors affecting such differences were the size and the quality of the business. On small farms, with poor crop yields and a poor quality of live stock, the sales but little more than covered expenses. On large farms, with good crop yields and good live stock, the sales far exceeded the expenses.

In five years there was a decided change from sheep to cattle. Sheep decreased 58 per cent and cattle increased 68 per cent. The decrease in sheep was greater on farms that kept sheep primarily for wool production than on farms selling lambs and wool.

When this study began, butter was the only dairy product sold; at the end of the five-year period several farmers were selling cream. The sale of dairy products increased \$50 per farm.

Putting up silos aided several farmers to carry more live stock.

Corn yielded 44 bushels per acre for the five-year average, wheat 14 bushels, and hay 1.2 tons. Yields for the different crops were 50 to 100 per cent better some years than others, but in no case did all the good yields or all the poor yields fall in a single year. The amount of feed raised each year varied less than the yields of individual crops.

Price levels increased 23 per cent from 1912 to 1916, and operating expenses 11 per cent.

There were much wider variations in the amount of crops sold than in the live stock sold. For two years the quantity of all products sold approximated the five-year average, for two years it was above the average, and for one year decidedly below.

GENERAL DESCRIPTION OF AREA.

LOCATION.

Palmer Township, Washington County, the area selected for this study, is in the hill section of southeastern Ohio and is representative of much of the hill land drained by the Ohio River. The town-

ship is strictly rural. There are no towns within its borders, and only two country stores. (See fig. 2.) These serve as markets for such produce as butter, eggs, and poultry. A few small towns (not railroad points) lie within close proximity to the township, and some of the farmers do part of their trading there.

TRANSPORTATION FACILITIES.

A secondary line of the B. & O. R. R. extending along the Muskingum River from Zanesville to Marietta and Parkersburg and reach-



FIG. 2.—A representative church, schoolhouse, and country store. Palmer Township has three churches, seven schools, and two country stores.

ing to within 4 miles of the area furnishes railroad facilities for the farmers in the northern part of Palmer Township. Each terminus of this line connects with main lines of the B. & O. system. Another railroad through the hill section from Marietta to Palos, thence connecting with other lines to Columbus, reaches to within 5 miles of Palmer Township, and had furnished shipping facilities to those farmers living in the southern part until it was abandoned in the fall of 1916. The central part of the township is about equidistant from each of these railroads.

An electric line from Beverly to Marietta and Parkersburg, terminating within 6 miles of the northern boundary of the township, is of much service to these people in reaching Marietta, the county seat, a city of some 13,000 population. The average distance of all farms studied from their railroad market point is 6.3 miles, with a range of from 4 to 9 miles.

None of the wagon roads within this area are macadamized. Those extending to the railroad points are also unimproved except about 1 mile out from Waterford, the first half mile of which is paved with brick, and the second half mile macadamized. The wagon roads, often very hilly, are usually dry and smooth during the summer and fall seasons, but become very muddy or rough during the winter and spring months.

HISTORY.

In Washington County is the oldest white community within the State of Ohio, Marietta, situated where the Muskingum River joins the Ohio, having been settled in 1788. On May 19, 1851, what had formerly been parts of Waterford, Watertown, Roxbury, and Wesley Townships were organized into Palmer Township, which took its name from one of the pioneer families. The first settler in what is now Palmer Township moved there in 1796. Two great grandchildren of this pioneer are now farmers in the township. As early as 1806 a teacher was engaged to teach a school in Palmer Township. Religious meetings were customarily held in private houses until, in 1837, a Methodist church was built. The first store was opened about 1825. Contrary to the usual custom of making first settlements along the streams, those of Palmer Township were made on the higher plateau-like land back from the streams.

The early agriculture of this area differed little from that of the present day in the main crops grown or in the classes of live stock raised. Since the early settlement corn, wheat, and hay have been the important crops, and horses, cattle, sheep, hogs, and poultry the live stock kept. From time to time there have been adjustments and readjustments in the farm organization, which have resulted in variations in the comparative importance of different crops and of different classes of stock, but not in a permanent elimination of any of those named.

In 1902 or 1903 oil was discovered in the township. The development was rapid, reaching its maximum in 1905. After 1907 only an occasional well was drilled, until 1915, when development revived. Only 6 of the 25 farms upon which five-year records were taken and but 10 of the 73 farms included in this survey have had any oil production. Oil production has added somewhat to the income of some

of the farms studied, but all income from this source has been ignored in connection with the study herein presented.

The population of Palmer Township, by 10-year periods, was as follows: In 1860, 618; in 1870, 671; in 1880, 591; in 1890, 541; in 1900, 614; and in 1910, 621.

SOILS.

The soils of Palmer Township have been described under the general classification residual shale and sandstone soils.¹ These soils, underlain by shales and sandstone, have given rise to two distinctly different soil series, the Dekalb and the Upshur.

The Dekalb is represented in this township by a type known as Dekalb silt loam. The soil of the Dekalb silt loam is a grayish yellow or light yellowish brown mealy silt loam, varying in depth from 6 to 12 inches, with an average of about 9 inches. The typical soil has a smooth, velvety feel and is rather mellow and easily tilled, although it has a slight tendency to run together. In cultivated fields the surface soil when dry is usually a very light gray with a pale yellowish tinge, but when moist, as in freshly plowed fields, the color is more nearly a light yellowish brown. As a rule, the Dekalb silt loam has very little, if any, lime carbonate present, and over a large part of the area, particularly in poorly drained places, there is undoubtedly a deficiency of lime. On the whole, the Dekalb silt loam is not considered a very productive soil without fertilizers. One of the principal needs of this type is organic matter, which may be supplied by the growing and turning under of clover, rye, or other green manuring crops, or by the addition of stable manure, to which this soil gives a ready response. The texture of the subsoil is such that it is retentive of fertilizers, and a permanent improvement of the land may be brought about by proper cultivation and fertilizers.

The Upshur series is represented by the Upshur clay, which is known throughout the section where it occurs as "red clay land." The type consists of an Indian-red, purplish-red, or reddish-brown, heavy clay loam to clay, underlain by a red, very heavy, plastic clay, which extends to a depth of 3 feet or more. In its typical development there is very little difference between the soil and the subsoil, but in some areas the red clay is overlain by a thin layer of material which is lighter both in color and in texture. The type is very plastic, and sticky when wet, and it cracks badly upon drying, the cracks varying in width from one-fourth to three-fourths of an inch, and extending in many cases to the depth of a foot. This soil erodes

¹ See Reconnaissance Soil Survey of Ohio, Advance Sheets, Field Operations of the Bureau of Soils, 1912, U. S. Department of Agriculture, pages 36-45, from which the above soil description and much of the topographical description is abstracted.

easily, and for this reason much damage has been done by washing. On the whole, the type is a rather strong soil, and were it not for the steepness of the slopes and the difficulty of cultivation it would be prized much more highly than it is.

Under the residual shale and sandstone soils another series of soils, designated the Meigs series, has been established. It represents a

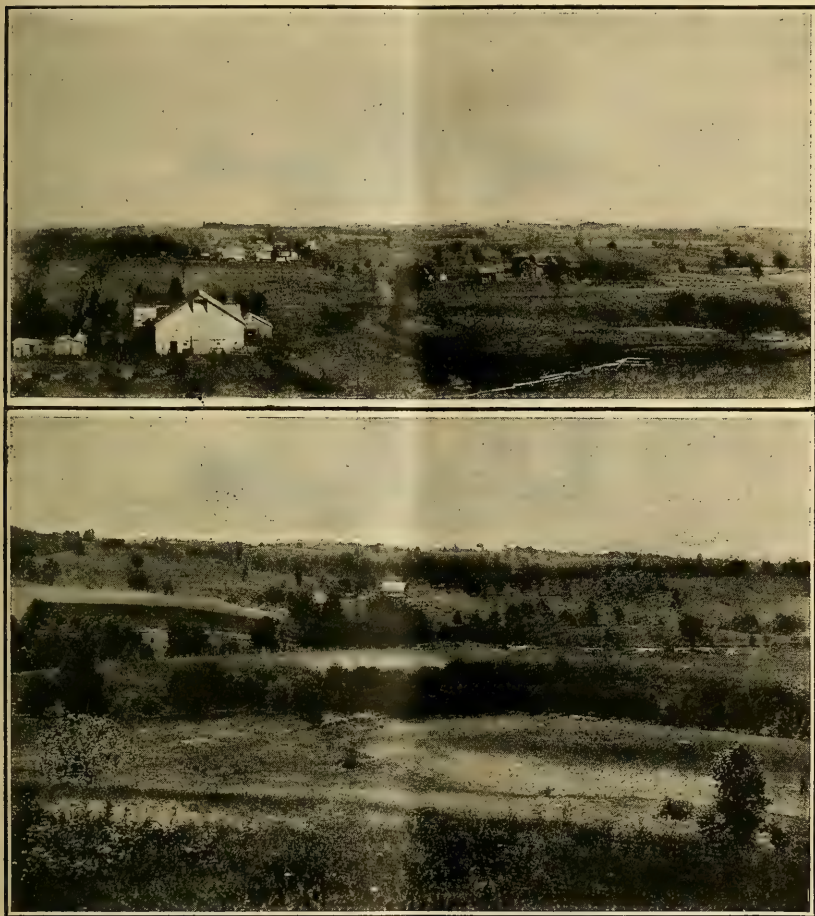


FIG. 3.—Scenes representative of the topography of Palmer Township. In the upper picture the surface features grade from rolling to hilly, with steep slopes occurring here and there. In the lower picture the greater part of the surface grades from hilly to steep, with occasional small areas of rolling or plateau-like land near the crests of the slopes. Approximately one-half of the entire surface of these farms grades from rolling to hilly, and one-third from hilly to steep.

gradation between Dekalb silt loam and the Upshur clay, or a mixture of the materials constituting them.

The farmers' estimates of the proportion of their farms represented by each of these soil types were as follows:

Dekalb silt loam (locally known as white or yellow soil), 44 per cent.

Upshur clay (locally known as red clay land), 8 per cent.

Meigs (locally known as mixed soil), 48 per cent.

TOPOGRAPHY.

The hill country proper of Ohio, which includes the township studied, is well described as consisting of a succession of hills and

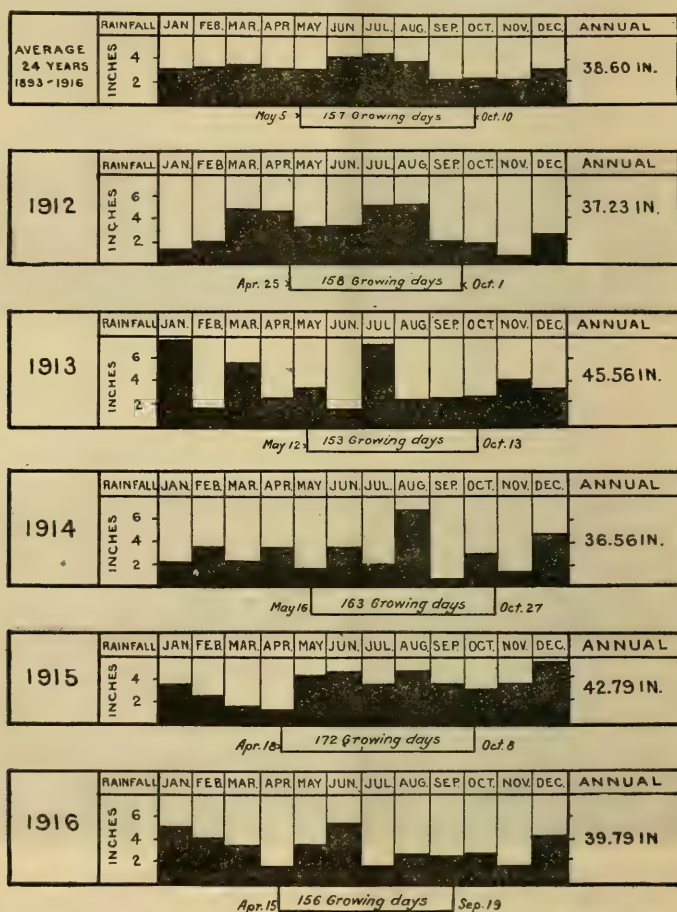


FIG. 4.—Monthly rainfall at Amesville, Ohio, for each year covered by the study, 1912 to 1916, inclusive, and the 24-year average, together with the number of growing days from the date of the last killing frost in the spring to the first killing frost in the fall.

sharp-winding ridges, separated by deep, narrow valleys. The hilly country represents the western extension of the Allegheny Plateau, which has been so deeply eroded and dissected that all remnants of the plateau surface have been removed. The greatest amount of dissection has taken place along the Ohio River and its larger tribu-

taries, where the hills rise rather abruptly to an altitude of 300 to 500 feet above the streams. As a rule the slopes are very steep and more or less benchy, while the crests of the ridges are narrow, sharp, and irregular. Back from the main streams (Palmer Township is so situated) the streams of a minor character have not cut so deeply, and the hill slopes, as a whole, are less steep, the crests of the ridges more rounded, and the altitude above the valleys is not so great. Throughout practically all of the hilly section the surface features are so uneven that the ridge-crest roads are not free from heavy grades. (See fig. 3.)

The elevation of Palmer Township varies from 680 to 955 feet above sea level.¹ Most parts are very steep and broken, but there are several small areas with surfaces slightly rolling. Large unbroken fields, however, are seldom found.

CLIMATE.

The region is one of cool winters, the average winter temperature being about freezing. The summers are moderately hot, with an average temperature just above 70°. The rainfall is about 40 inches a year. March usually has the largest number of rainy days, the average being 12, and September the smallest number, with an average of 7.

The diagrams in figure 4 show graphically the monthly rainfall and the growing season, from the last killing frost in the spring to the first killing frost in the fall, for each of the years included in the survey; also the average rainfall during the last 24 years and the growing season during the last 13 years.²

TYPE OF FARMING.

The farmers of this section practice a general or mixed type of farming, which doubtless has been partly determined by the topography, the character of the soil, and the marketing facilities. About one-half of the land is used as pasturage for beef cattle and fine-wooled sheep, and one-fourth in growing feed crops for the live stock kept on these farms. The type here followed is practically the same as that found throughout the hill section.

Of the crops grown, corn, wheat, and hay are considered the major crops, while oats and soy beans are frequently grown as minor crops. More of each of these crops is used on the farms for feed, seed, or household purposes than is sold. Of the total production, one-third of the wheat is sold, one-sixth of the hay, one-tenth of the oats, and

¹ Topographical map of the State of Ohio, U. S. Geological Survey.

² The data contained in this graph were compiled by Mr. W. G. Reed from the observations of the U. S. Weather Bureau located at Amesville, Athens County, Ohio, a distance of 14 miles, and with weather conditions similar to those in Palmer Township.

one-eighteenth of the corn. Practically all farms have small apple orchards. Most of these were intended primarily for home use, although a few are used commercially in a small way after the household needs have been supplied.

In addition to beef cattle and fine-wooled sheep, nearly one-half of the farms have flocks of over 150 chickens, and these form one of the important enterprises of the township. The production of market hogs is also important, although somewhat limited on account of the limited production of corn. Some of the farms raise one or two colts a year, but the production of colts for the last five years has been of comparatively minor importance for the entire township.

FARM TENURE.

Only a small percentage of the farmers in Palmer Township were tenants. This condition holds good for the entire hill section. The 1910 census shows that 18 per cent of the farmers in the hill counties of Ohio were tenants, while in the more level counties of the State, 31 per cent were tenants. Some owners in this area rented other land, usually a field or two, which they farmed with their own land as a farm unit. Since there were so few tenants, and the additional acreage rented by owners was so small in most cases, the data for such farms have been summarized and used in this bulletin as though the operator owned all the land he farmed.

METHOD OF STUDY.

During November and December, 1912, the writer visited the farmers of Palmer Township and made a record of a year's business transactions of these farms, together with an inventory of the farm investment for the beginning and the end of the farm year.¹ This year extended from November 1, 1911, to November 1, 1912, and it is designated as "the farm year 1912" in this bulletin. This visit was repeated each fall for four additional years, and records of each year's business transactions were taken.²

Each year some records were eliminated, because a large proportion of the operator's time was engaged in teaming or in some other occupation not directly connected with the farm business; because the operator rented out a considerable proportion of the crop acreage; or because the record was incomplete or obviously inaccurate.

Usable records were obtained for five years on 25 farms, and for one, two, three, or four years on 48 other farms. In this study one

¹ An outline showing a method of analyzing the farm business, together with copies of the blank forms used in this survey, may be obtained by applying to the U. S. Department of Agriculture for Farmers' Bulletin 661.

² During the visit in 1915 the writer was assisted by Mr. R. D. Jennings, and in 1916 by Mr. Earl D. Straith, both of the Office of Farm Management.

of the objects was to determine important yearly variations. This is best done by comparing the same farms over the five-year period. A study, based upon the data for the farms with the five-year records is, therefore, presented below.

A FIVE-YEAR STUDY OF 25 FARMS.

When studying the farming of an area from a business standpoint some advantages are derived from extending the study over a period of years rather than limiting it to a single year. A study of the yields of crops, prices received for products, expenses incurred in operating the farms, etc., when extended over a period of years will give economic information that can not be obtained from the study of a single year. By extending the study over a period of years data are furnished that show the yearly variations of the many items that enter into a year's farm business, and that define the changes taking place in the agriculture of an area. Studies like these are best made by comparing results on the same farms for several years. In this area, usable records were obtained from 25 farms every year for five consecutive years. These farms were quite representative of all those in the area, and the results derived from the study of this group, whether by years or for the entire period, should

¹ Certain terms used in this bulletin are here defined:

Farm investment.—The value at the beginning of the farm year of all real estate, machinery, live stock, and other investment used to carry on the farm business. It includes the value of the farm dwelling, but not the household furnishings.

Receipts.—The amount received from the sale of crops, the net increase from stock, and the receipts from outside labor, rent of buildings, etc. The net increase from stock is found by subtracting the sum of the amount paid for stock purchases and the inventory value at the beginning of the year from the sum of the receipts from stock products, sales of live stock, and the inventory value at the end of the year. If the value of crops or supplies on hand was greater at the end of the year than at the beginning, the difference was considered a receipt.

Expenses.—The amount of money paid out during the year to carry on the farm business, together with the value of the unpaid labor performed by members of the family. If the value of crops or supplies at the end of the year was less than at the beginning, this was considered an expense. Household or personal expenses are not included.

Farm income.—The difference between receipts and expenses. It represents the amount of money available for the farmer's living above the value of family labor, provided he has no interest to pay on mortgages or other debts.

Labor income.—The amount that the farmer has left for his labor after 5 per cent interest on the farm investment is deducted from the farm income. It represents what he earned as a result of his year's labor after the earning power of his investment has been deducted. In addition to the labor income the farmer received a house to live in, fuel (when cut from the farm), garden products, milk, butter, eggs, etc.

Per cent on investment.—The rate returned on the farm investment after the value of the farmer's labor is deducted from the farm income. It represents what the investment earned after all expenses have been deducted and the farmer has received a fair wage for his labor.

Animal unit.—In order to compare the different classes of animals and to compute the total amount of live stock on these farms all stock has been computed in terms of animal units. In this area one horse, cow, or steer was counted as one animal unit; two head of young stock (of the above kind) were counted as one animal; 10 sheep, 5 hogs, or 100 chickens were each counted as one animal unit. The number of productive animal units includes all stock except work stock.

prove a source of valuable suggestion to other farmers of the community. The greater part of the following discussion centers around this group of 25 farms.

SUMMARY OF THE FARM BUSINESS.

A brief summary of the business conducted on these farms is presented in Table I. The data shown are averages for the 25 farms for each year from 1912 to 1916, with the five-year average in the last column.

TABLE I.—*Summary of the farm business of 25 farms for a period of five years 1912-1916 (Palmer Township, Washington County, Ohio).*

Item.	Averages, all farms, by years.					Five-year average
	1912	1913	1914	1915	1916	
Farm area.....acres..	158	156	156	154	156	156
Crop area.....do.....	44	42	39	44	46	43
Number of productive animal units.....	13.5	14.4	15.3	14.9	16.1	14.9
Number of work stock.....	2.6	2.7	2.6	2.8	2.7	2.7
Investment.....	\$6,087	\$6,214	\$6,422	\$6,527	\$6,639	\$6,378
Receipts.....	868	796	934	916	1,112	922
Expenses.....	412	375	423	430	456	419
Farm income.....	456	421	511	486	656	503
Interest on investment, at 5 per cent.....	304	311	321	326	332	319
Labor income.....	152	110	190	160	324	188
Value of farmer's labor.....	\$288	\$281	\$295	\$290	\$298	\$293
Per cent on investment ^a	2.8	2.2	3.4	3.0	5.4	3.1
Farm income.....	\$465	\$421	\$511	\$486	\$656	\$503
Value of unpaid family labor.....	86	85	92	90	82	87
Family income ^b	542	506	603	576	738	590
Interest paid on indebtedness.....	19	19	14	12	6	14
Amount available for family living.....	523	487	589	564	732	576
	Percentage of five-year average.					
	1912	1913	1914	1915	1916	
Crop yields.....per cent..	110	89	94	106	101	96
Receipts per animal unit.....do....	93	97	99	98	113	99
Price received for farm products.....do....	91	98	99	100	112	99
Quantity of farm products sold.....do....	108	81	101	101	109	96

^a After deducting farmer's labor from farm income.

^b The sum of farm income and value of unpaid family labor, or the amount available for family living had there been no interest to pay.

For the five-year period the farms averaged 156 acres, with almost one-fourth of the area in woodland and wasteland. The surface features being somewhat hilly or broken, only 43 acres per farm were used in producing crops, with about one-half of the farm area left for pasture land. Most of the crops were fed to the stock kept on these farms. There were 2.7 work horses per farm and other live stock equivalent to 14.9 horses or cows, cattle comprising more than one-half of all the productive live stock.

The farms were worth about \$30 per acre, and this, with the value of the live stock, machinery, etc., represented a farm investment of

\$6,378. This investment, together with the farmer's own labor, returned receipts amounting to \$925 per year, \$419, or 45 per cent, of which were used for expenses in connection with the farm business. After deducting the expenses from the receipts, the farm income, or the combined earning of the investment and the farmer's own labor, was \$506. With money worth 5 per cent, and this was the average rate paid by those in the area who borrowed, the farm investment should have earned \$319. This amount deducted from the farm income leaves \$187 for the farmer's own labor, or his labor income. On the other hand, if the value of the farmer's labor, which he estimated at \$290, be first deducted from the farm income, there is left \$216, or 3.4 per cent, for the earning of the farm investment. If to the farm income be added \$87, the value of the unpaid family labor which was included as an expense, and then \$14, the amount of interest paid on borrowed money, be deducted, there is left \$579, or the amount of money available for the use of the farmer and his family.

It is well understood that a very significant proportion of the farmer's living is furnished directly by the farm. This may be considered as an addition either to the labor income or to the per cent on investment. Data from 16 farm families in Palmer Township show that the total value of three important items of the farmer's living—food, fuel, and use of a dwelling—was \$400 per family. Of this amount \$325, or \$90 per person, was furnished directly by the farm. The farm furnished in food products \$215 per family and in fuel \$23, the use of the dwelling being valued at \$87. Of the items bought food cost \$61 per family and the fuel \$14. The average family in this area consisted of 4 persons, or the equivalent of 3.6 adults.

From this table similar studies of the summary of the farm business may be made for each of the years over which the survey extended, and comparisons of the summaries, one year with another, will show the main points of difference for the various years.

The crop acreage did not vary more than an acre per farm from the five-year average except in 1914, when it was 4 acres below the average, and in 1916, when it was 3 acres above the average.

The number of productive live stock increased 20 per cent during the five years, and was accompanied with a change from sheep to cattle, the number of cattle increasing 68 per cent and that of sheep decreasing 58 per cent.

The farm investment increased each year until at the close of the period it was \$552 more per farm than at the beginning. The increase in the amount of stock and the higher live-stock prices account for more than one-half of this higher investment.

The farm receipts for three years were within 6 per cent of the five-year average receipts, for one year they were almost 15 per cent below the average, and for the other year they were 20 per cent above the average.

The farm expenses increased each year except in 1913, when they were lower than for any other year. The sales were also the lowest in 1913.

The farm profits, whether measured by the labor income or by the per cent on the investment, were within 20 per cent of the five-year average for three of the years, while in 1913 they were about 40 per cent below the average, and 70 per cent above in 1916.

In 1912 one-third of the farmers were in debt, the indebtedness varying in amount from \$150 to \$3,000; in 1916 only 1 in 6 was in debt. During this period the mortgages on four farms were paid off with money made from the farming, and on three others the mortgages were decreased, while the amount was increased on but one. Indebtedness decreased more rapidly during the years showing greater profits, while in 1913, the year returning least profits, there was no decrease in the indebtedness.

The yield per acre of crops, the receipts per animal unit from live stock, the price received for products, and the amount of the products available for sale are all important factors with considerable variations during the different years. For comparison these are shown for each year in the summary table (Table I) as percentages of the five year average.

The yield per acre of the more important crops for the different years varied from 89 per cent to 110 per cent of the five-year average; the receipts per animal unit from 93 per cent to 113 per cent; the price received for farm products from 91 per cent to 112 per cent; and the quantity of products sold from 81 per cent to 109 per cent.

THE FARM AREA.

The farm area for a farm includes the entire acreage operated as one farm. The land may be all owned by the operator, it may be all rented, or it may be partly owned and partly rented. Of the farm area included in this group of farms 90 per cent was owned by operators, 8 per cent cash rented, and 2 per cent share rented.

The slight variations in the farm area from year to year shown in Table I were due to variations in the acreage owned by four farmers—one selling part of his farm and three buying more land—and to yearly variations in the acreages share rented by a few farmers. The land share rented usually represented single fields and included fields in corn, wheat, oats, and hay.

About 95 per cent of the entire acreage was owned or cash rented throughout all the years, and the changes in farm area that did occur were confined to a small percentage of the entire acreage included in the 25 farms.

Land, including buildings, was valued at \$30 per acre in this area. Fourteen per cent of it was too rough for cultivation at all, and regarding a much larger percentage it is questionable whether it should be cultivated. From figure 5 a general idea may be formed of the way the land was utilized. It shows the proportion that was still in woodland or waste land, the proportion that was used for pasture land, and that used for growing crops. This distribution of the farm area was rather uniform for the different years, the more important changes over the five-year period being a decrease in the proportion of woodland and waste land, with an increase in the proportion of crop land.

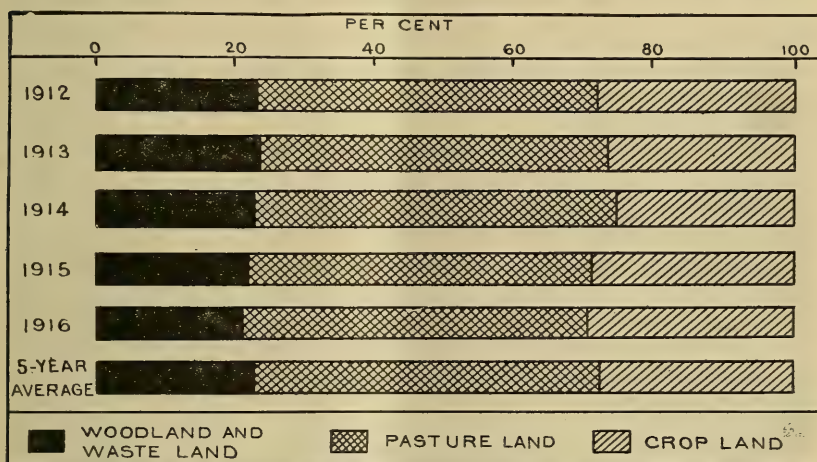


FIG. 5.—Distribution of farm area on 25 farms, Palmer Township, Washington County, Ohio.

WOODLAND AND WASTE LAND.

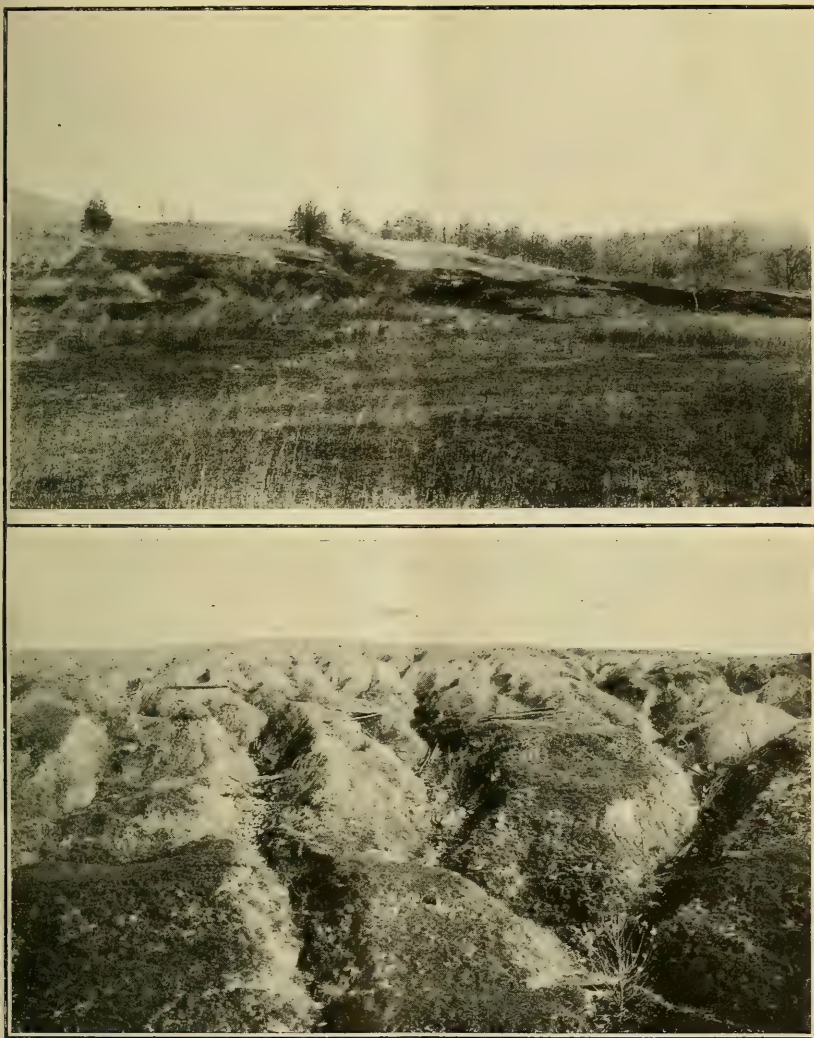
About one-fifth of the total farm area, or 34 acres per farm, was woodland and waste land. In 1912 the acreage of each was almost equal. The acreage of waste land remained constant during the entire five-year period, but that of the woodland decreased each year until in 1916 it was only about 70 per cent of the waste land. This was due to selling timber, or having it sawed into lumber, either for sale or for use on the farms. The total acreage of woodland was 432 acres in 1912, with a decrease each succeeding year until it was 327 acres in 1916. This means that 105 acres were cut off during the five years, or about five-sixths of an acre yearly per farm. There is

still left an average of 13 acres of timber per farm, varying from none to 64 acres on different farms. At this rate the present timber



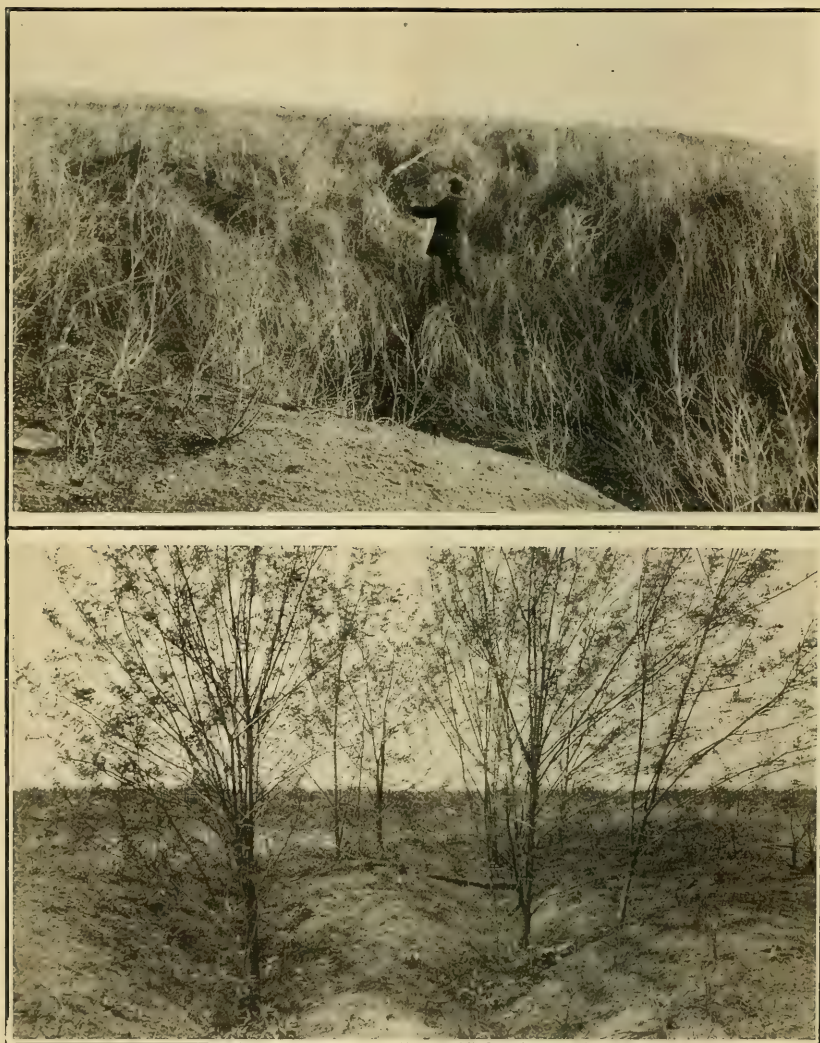
FIG. 6.—Second-growth white oaks about 50 years old. This block is about 5 acres in extent. Small areas of second-growth white oaks are found on several farms. Most of them are younger and not as large as those shown in the picture.

supply would last about 16 years, but it is probable that the timber will not be cut off at so rapid a rate in succeeding years as during the five years.



ERODED LAND.

The upper picture shows eroded land, the result of a few years' neglect after slight breaks had occurred in the sod. The lower picture shows that continued neglect has resulted in the disappearance of all grass, and in the deeper gullying of the land.



RECLAIMING ERODED LAND.

The upper picture shows the growth made by sweet clover that was sown broadcast on land after it had reached the condition shown in the lower picture in Plate I. The lower picture shows how erosion has been checked and the washes filled in after locust sprouts had been growing in the ravines of the washes for three years.

Some of the land that was cut over during the five years was cleared and either seeded for permanent pasture or used for growing cultivated crops. However, the larger portion of it remains uncleared and is growing to brush and briars. This is true also of some of the land that had been cut over a few years prior to 1912. On land that has been left this way for several years second growths of the native timber trees are noticeable, and on some of the more open parts bluegrass has obtained a stand.

Most of the land that was cut over about 20 years ago has since been handled in one of the following ways:

(1) Cleared and used for cultivated crops.

(2) After clearing, used for permanent pasture, the pasture grasses having come in voluntarily or the land having been seeded for pasture.

(3) Some blocks or clusters of second-growth white oaks that give promise for future timber supplies are permitted to remain, the underbrush in some instances being removed and in others not.

(4) Young white oaks and black walnuts when more or less scattered are sometimes permitted to remain, all less desirable species and the underbrush being removed. The land is afterwards used for pasture, the grasses coming either spontaneously or from seedings.

Figure 6 illustrates the practice described as the third method. These white oaks were estimated at about 50 years old. The photograph was taken from a block about 5 acres in extent.

Blocks of younger trees on other farms bid fair to equal these in time. On several farms part of the cut-over land has been handled as described under methods 3 and 4. With a yearly decrease in the available timber supply, it is most probable that similar practices will be used with parts of the more recently cut-over lands. To say the least, such practices are well worth consideration.

Old locust trees are scattered over the township, having been planted years ago near buildings or along fences. Clusters of young locusts are found here and there, where they have spread from the roots of stumps or from seeds scattered from older trees. On a few farms locust groves have been set out. The locust borer is a serious problem to those who desire or have tried to grow locusts. When old trees are made into posts the effects of this insect's work are readily seen, and young trees are frequently killed by this pest. In spite of the borer, however, locusts are grown in the township, and an attempt should be made to grow them on every farm. They may furnish posts for the farm, but even if they should not, they are well worth trying on rough land that is producing little or no pasture. The pasture in all probability will be improved.

Part of the waste land of this area is the result of erosion. Unprotected soils on these hillsides erode easily. Any slight breaks in the sod furnish starting places for washes and after a few years' neglect often result in a condition much like that shown in the upper illustration in Plate I. If neglected a few years longer gullies similar to those shown in the lower illustration may be worn. On several farms are areas where conditions prevail similar to those indicated in one or both of these illustrations. Such areas vary in extent from small fractions of an acre to 15 acres or more. These conditions, prevalent throughout the hill section, exist through neglect. When small breaks in the sod are first made a little grass seed and manure scattered over the bare soil will prevent further washing; but the longer the matter is neglected the more difficult it is to overcome.

The upper picture in Plate II shows sweet clover growing on land that had reached the stage indicated by the lower illustration in Plate I. While the work was only experimental, it indicates what may be done to reclaim such land. In the spring of 1913 one-half bushel of white sweet-clover seed (hulled) was sown on 4 or 5 acres of this land. The stand obtained was by no means perfect, but it was encouraging. The plants that grew from this seeding matured seed in the fall of 1914 (the white sweet clover being a biennial) and reseeded themselves. The illustration was photographed in November, 1916, shortly after the reseeding had matured its crop of seed and the foliage had dropped off. It indicates the stand obtained and the growth made from the reseeding. In a number of places on this land bluegrass and white clover were already coming in at that time.

On an adjoining farm 25 locust sprouts were set in the ravines of washed land, also in the spring of 1913. Most of these lived, and in the spring of 1917 the washes where they grew were about one-half filled in. (See lower picture, Pl. II.)

These simple experiments indicate that sweet clover sown on eroded areas and locust sprouts set in the gullies are effective means in checking erosion. The sweet clover is also a soil improver and an excellent forerunner for bluegrass pastures. It should be noted that the sweet clover thrives better on the red than on the white or yellow soils.

PASTURE LAND.

Pasture land comprises about one-half of the farm area. Fully two-thirds of the pasture land admits of cultivation, but when considering how difficult it is to cultivate and how easily the soil erodes it is hardly advisable that much of it be broken, except for occasional reseeding. Only a small proportion of the total pasture land was included in the rotation area.

The acreage used for pasture land was rather constant, the yearly range averaging from 75 acres to 79 acres per farm. The carrying capacity of this pasture land was about 5 acres per horse, cow, or equivalent, but the number of acres so required varied widely on different farms. During the five years 10 of these farms carried the equivalent of a horse or cow on 4 acres or less of pasture, while on 8 farms it required 6 or more acres of pasture land for the equivalent of each cow or horse. With about one-half of the land used for grazing and with so large a proportion of the farm receipts from live stock, the carrying capacity of the pasture land is of major importance to the farmers of this region. The practices in handling the pastures on those farms that carried as much stock on 4 or less acres of pasture land as others did on 6 or more are worthy of careful study—a closer study, indeed, than has been given them through this survey.

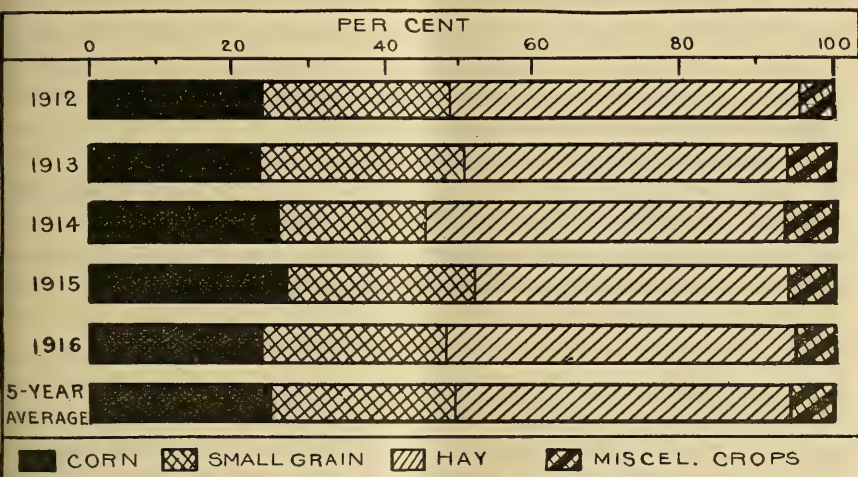


FIG. 7.—Distribution of crop area on farms studied.

THE CROP AREA.

The yearly range in crop acreage on the 25 farms has been shown in the summary table (Table I). The five-year average was 43 acres per farm. In 1916 it was 2 acres more per farm than for any other year, and in 1914 it was 3 acres less per farm than for any other year. This was the year with least wheat acreage, and it was to it that the greater part of the shortage in crop acreage in 1914 was due.

The distribution of the crop area for the years covered by this study is shown graphically in figure 7.

CORN.

About one-fourth of the crop area was in corn. These farmers aim to produce all of the feed used on the farm, and during the five

years they produced 90 per cent of the concentrates used and practically all the roughage. They considered corn their most important cereal and the cheapest source of concentrates. The importance of corn in furnishing feed for the live stock of this area may be seen from Table X, page 42. During this five-year period 56 per cent of the total feed requirements, exclusive of pasture, was supplied by corn—75 per cent of the concentrates and 32 per cent of the roughage. All farmers raised corn and much the greater part of it was grown from grain. Occasionally on a few farms a small acreage of the corn was planted so late or had eared so poorly that it was harvested for fodder only. Of the total corn acreage for the five-year period about one-sixth was used in growing corn for the silo.

Prior to the period covered by this survey there had been but one silo in the township, and it was put up in 1911. The number of silos has increased until at the close of the five-year period, November 1, 1916, there were 22 in the entire township, the greater number of which were built in 1915 and 1916. Of course, the proportion of the corn acreage grown for the silo has increased each year and decidedly so in the last two years. In 1912, 12 per cent of the corn acreage on the 25 farms was put in the silo and in 1916, 30 per cent. Whether or not putting up silos has increased the corn acreage on those farms can not be stated positively, yet the data show that on the farms which had silos during the last two years, but did not have them during the first three years, the corn acreage for the last two years had increased 13 per cent over that of the first three years, and that on the farms which have no silos the corn acreage for the last two years has increased but 5 per cent over that of the first three years. No doubt these silos were built in order that more stock might be kept, an assumption substantiated by the data from the farmers with silos and from those without. On the farms that put up silos the amount of stock kept has increased 22 per cent, while on the farms that did not put up silos the amount of stock increased but 5 per cent, or just as much as the corn acreage was increased. While the farmers who put up silos increased the amount of stock kept much more than they increased their corn acreage, yet this greater increase was not altogether because of the silos, for there was also an increase of \$2.57 per animal unit in the amount of feed bought. By increasing the corn acreage 13 per cent, building silos, and purchasing a small additional amount of feed, they were enabled to keep 22 per cent more stock than they had been keeping.

A few farms were found which occasionally grew small acreages of cowpeas or soy beans, which were mixed with the corn when filling the silos.

SMALL GRAINS.

The total acreage of all crops that have been classed as small-grain crops equaled the corn acreage. These include wheat, oats, rye, timothy seed, soy beans, field beans (navy), and buckwheat.

Of these crops, wheat was of much the greatest importance, occupying about 80 per cent of the small-grain acreage. With the yields and prices usually received, many of the farmers think that growing wheat on an extensive scale would not be very profitable. Yet all of these 25 farmers usually grew limited acreages of wheat. The reasons given for growing some wheat were that it fitted well in a rotation, it was a good nurse crop for grass seedings, it was a good feed for poultry, it supplied the family with flour, and the straw furnished bedding for the live stock.

In 1914 the crop acreage was less than for any other year. This was the year with least acreage in the small grains and with the smallest proportionate acreage in small grains. This was due to a decrease in the wheat acreage.

The yearly data on wheat production on these 25 farms are shown in Table II. The point of main interest in this table is the effect of yield per acre upon the acreage sown for the following year. In 1912 the yield per acre was 14 bushels, or the same as the five-year average. Following this normal yield, a normal acreage was sown for the 1913 crop, which yielded only 9 bushels per acre. Following this low yield, two of the farmers who had been raising wheat did not sow any, and those who did sow decreased their acreages almost 25 per cent. The 1914 crop, however, produced 18 bushels per acre. The good yield for this year, together with the good prices received, was such a stimulus to greater effort for 1915 that all but one of the farmers sowed wheat, and the acreage was greater than for any previous year. The resulting crop was the largest for the five years, and, although more of this wheat was fed on the farms than during previous years, receipts from the sale of wheat were more than for any other year. The acreage for the following year was as large as that of 1915, but the yield per acre dropped to 11 bushels. It will be noticed that the amount of wheat used on these farms totaled almost 500 bushels more during 1915 than during any other year. With the larger wheat production, some of the farmers thought it better to feed wheat to poultry and hogs than to sell the wheat and buy the feeds. The price of wheat being high in 1916, all farmers sold more closely, and as a result less was used on the farms than during other years.

TABLE II.—*Total acreage and production of wheat on 25 farms for five years, 1912-1916 (Palmer Township, Washington County, Ohio).*

Item.	1912	1913	1914	1915	1916	5-year average.
Number of farms producing wheat.....	23	23	21	24	23	23
Acreage of wheat.....	230	240	164	254	254	228
Yield per acre, bushels.....	14	9	18	18	11	14
Production of wheat, bushels.....	3,353	2,184	2,918	4,616	2,540	3,122
Quantity of wheat used, bushels <i>a</i>	1,932	1,797	2,040	2,536	1,728	2,007
Quantity of wheat sold.....	1,421	387	878	2,080	812	1,115
Receipts from wheat.....	\$1,393	\$375	\$1,046	\$2,398	\$1,230	\$1,288
Price received per bushel.....	\$0.98	\$0.97	\$1.19	\$1.15	\$1.52	\$1.16

a Includes that used for bread, seed, and feed.

Only about one-half of the farmers raised oats, and statistics show that less of this crop is grown than in former years. The principal reason for this is the low yield per acre, which is usually less than 30 bushels, a very low feed value per acre. In Palmer Township, where the acreage that can well be devoted to cultivated crops is somewhat limited, it is a good farm practice to grow crops that return a comparatively high feed value per acre. An acre of corn in this area produced fully $2\frac{1}{2}$ times the feed value that was produced from an acre of oats. Fields with poor stands of grass were sometimes plowed, sown to oats, and seeded again to grass. This practice is followed almost as frequently as that of growing oats in the regular rotation.

Rye has occupied an unimportant place in the crop acreage of Palmer Township. Only a few of the farmers raised rye, and then only for an occasional year or two. It was usually seeded instead of wheat, but has made very little progress in displacing wheat.

The other crops included under small grains were grown in small acreages and on scattered farms. They were of little importance to the township as a whole.

HAY.

Hay occupied 46 per cent, or almost one-half of the crop acreage. The main hay crop consisted of either clover or timothy, or clover and timothy mixed. The clover and timothy was often still further mixed with bluegrass or redtop, especially if the meadows were of more than two years' standing.

Such crops as oats, wheat, rye, millet, sorghum, cowpeas, and soy beans were occasionally reported used for hay. These occurred as small acreages, and combined they totaled only 4 per cent of the hay acreage.

Soy beans for hay have grown somewhat in favor with a number of farmers during the period of this survey. One farmer grew 2 acres in 1912 and four farmers grew 11 acres altogether in 1916. Five grew soy beans for hay in 1914, to supplement the main hay

crop, which yielded less than a ton per acre that year. Most of these men prefer the soy bean to the cowpea for a hay crop, believing it better adapted to local conditions. In growing the soy bean for hay it is essential to use varieties that make a good growth. Farmers in this area have found the medium green and some of the black varieties best adapted for hay production. They have learned also that unless soy beans have been grown on the land in recent years inoculation gives better growth.

Wheat, oats, and rye, when used for hay crops, represented acreages on which these crops had wholly or partially failed as grain crops, or for some other reason could not well be harvested as grain.

When millet, sorghum, soy beans, or cowpeas were sown for a hay crop, it was usually done in order to meet an anticipated shortage in the main hay crop. Sorghum has been grown for hay by a few farmers for several years, and with good report in most cases. Soon after cutting, it was piled in bunches in the field, where it usually remained until during the winter, when it was hauled and fed.

Some attempts to grow alfalfa have been made in Palmer Township, but most of them have failed. On the other hand, a few successes have been reported, and alfalfa can probably be grown with some degree of success on part of the land in the township. However, it must be borne in mind that the drainage, lime, fertility, and inoculation requirements of the plant must be met before it can be grown successfully.

Some farmers harvested the second crop of clover for seed. A few harvested clover seed nearly every year, while others had only an occasional crop, and 6 of the 25 had none during the entire period. The few farmers who usually had a crop of clover seed were thus enabled to supply their own needs and have a small surplus for sale. If more attention were given to growing clover, more seed could be harvested and thus the cash outlay for one of the main items in the expense for seed might be reduced. More attention should be given to growing clover, not merely for seed production, but to help maintain fertility and to furnish feed.

MISCELLANEOUS CROPS.

The area devoted to miscellaneous crops was about 5 per cent of the crop area, or $2\frac{1}{2}$ acres per farm. It included the acreage devoted to fruit, potatoes, annual pasturage crops, soiling crops, and green manure. Of these, fruit was the most important, occupying about nine-tenths of the miscellaneous crop area, or a little more than 2 acres per farm. The greater part of the fruit grown was apples, although most farmers had a few peach, plum, cherry, pear, and quince trees scattered about the dooryard, in the gardens or among the apple trees. The acreage devoted to these fruits was very small and so hard to measure that it was not estimated unless the trees

occupied a definite blocked-out area. These fruits were used almost exclusively in the homes; the sales from them averaged but \$4 annually per farm.

The land used for growing apples ranged from that occupied by a few scattered trees to 6 acres per farm. The apple orchards on one-half of the farms did not exceed 2 acres in size, and but 4 of the 25 farms had orchards of more than 4 acres.

Growing apples for commercial purposes has not been very profitable in this township, although the receipts of a few farms have been somewhat increased from this source. The average yearly sales of apples, including cider and vinegar, was \$28 per farm for the 25 farms, with only 1 farm exceeding \$100. Eight of them sold no apples during the five years. Southeastern Ohio is considered a very good section for apples, and much of the soil in Palmer Township probably is well adapted to apple production. Although the orchards of the township are fairly well cared for, pruned, sprayed, and in a few instances fertilized, few of them have been profitable. The actual yearly sales from the orchards in the last five years have been \$15 per acre. The main reasons for such low returns were:

Loss from frost. Some of the orchards are located on flat land, where they do not have good air drainage as protection from frost.

Uncertainty of the crop. But one farm of all those studied had enough apples every year to have some for sale after the household need had been supplied. Most of the orchards did not bear more than two or three years in the five.

The long haul to shipping point.

Low prices, averaging \$1.25 per barrel.

Some orchards had what are considered poor market varieties.

Rome Beauty, Grimes Golden, and Ben Davis are the leading market varieties of winter apples grown in this locality.

The potato acreage, aside from that of the home garden, was small, totaling 2 acres per year on six farms. For the five-year period barely enough potatoes were grown for home use. The farmers aimed to plant only enough to meet this requirement. With a good potato year some had a small surplus to sell, but with a poor year, and three of the five years were poor potato years, many of them did not raise enough for their own use.

On three scattered farms small acreages were sometimes planted to annual crops that were used for pasturage. The total area so used averaged 4 acres per year. Rye was most frequently grown for this purpose, although cowpeas, soy beans, oats, rape, and buckwheat were also reported. A few farms occasionally grew small acreages of corn, rye, or cowpeas that were fed green, and four farmers grew on an average $1\frac{1}{2}$ acres per year of rye, oats, soy beans, or cowpeas that were plowed under or disked in as green manure.

CLOVER AND LIME.

The farmers of this township have experienced difficulty in getting stands of clover; so much that some have quit sowing clover seed. When they were asked if they had any trouble in securing stands of clover, many replied, "Not if I top-dressed." Perhaps for this reason more manure has been applied as a top-dressing to wheat—to be followed with clover and timothy—than in any other manner. Most of these farms did not supply enough manure to top-dress all the wheat land each year, and the seeding of clover on these fields or parts of fields not top-dressed failed more often than on those that had been top-dressed.

Lime would aid materially in lessening the number of clover failures. Several of the farmers have used lime in a limited and experimental way within the last five years and with very few exceptions report favorable results. Most of them realize the importance of using lime, but they are at a disadvantage in getting lime to the farms, the haul is so long. The nearest available source of lime at present is a limestone crusher about a mile out from Waterford. This crusher is in operation at all times of the year when farmers would be likely to haul lime. Even though it is a big job to get lime to these farms, if each farmer would spend a day or two now and then in hauling lime, several tons could be put on each farm in a few years, and the results would be well worth the effort.

CROP ROTATION.

In the succession of crops in Palmer Township three rotation systems are practiced:

A three-crop system of corn, wheat, and grass.

A two-crop system of corn and grass.

A four-crop system of corn, oats, wheat, and grass.

The three-crop rotation was most common, with corn and wheat one year each and with a great variation in the number of years occupied by grass. Based upon this variation, the three-crop rotation may be divided as follows: A three-year rotation during which each crop was grown one year; a four-year rotation during which corn and wheat were grown one year each and grass two years; and a rotation of corn and wheat one year each followed by grass for an indefinite number of years, usually from two to five, but with extremes from one to seven years.

Only one farmer regularly practiced this three-year rotation throughout the five years, although two years ago another farmer shortened his rotation period to three years, reducing the grass for hay to one year instead of two.

A few farmers practiced the four-year rotation of corn and wheat one year each, and grass two years, but among those practicing a

three-crop rotation more grew corn and wheat one year each and then seeded to grass, which remained for an indefinite number of years, depending upon the number of years the grass maintained a good stand.

None of the farmers reported a definite time period for the two-crop rotation of corn and grass. Their main object is to keep a field in grass as long as possible. On the several fields used for the rotation, the one with poorest stand of grass is broken and planted to corn. In the fall, after the corn is cut, the land is prepared, in the same manner that land in corn was usually prepared for wheat, and seeded to grass alone. Usually clover is sown on this land the spring following. This practice seems to be just as successful in obtaining a stand of grass as when seeding with wheat.

A few farmers grew oats in their rotation, making a four-crop rotation of corn, oats, and wheat one year each, and grass for an indefinite number of years, usually two or more.

Some of the farmers reported no rotation, meaning that there was such irregularity in the succession of crops on their farms that no definite rotation prevailed. Following a crop of corn the land might be seeded to wheat or grass, or it might be bare over winter and seeded to oats the following spring. On individual farms with several rotation fields in grass, it frequently happened that there was a greater acreage with a poor stand of grass than the farmer cared to put in corn, in which case he sometimes put part of this acreage in oats and then seeded again to grass, and sometimes sowed wheat, followed by grass.

In all these rotations the grass crop was usually composed of timothy and clover mixed, although sometimes timothy was seeded alone, and occasionally redtop or bluegrass was seeded with the timothy or with the timothy and clover. In the three- and four-year rotations mentioned, the grass crop was invariably cut for hay, but in those rotations extending over an indefinite number of years, after being cut for hay from one to three years, it was sometimes pastured a few years.

The fact that practically one-fourth of the crop land was in corn, one-fourth in small grains (mainly wheat), and nearly one-half in hay, would seem to indicate that a four-year rotation of corn and wheat, one year each, and hay, two years, was a standard for this area. However, from a study of the individual farms, it by no means appears that a majority of the farmers practiced such rotation. Yet the farmers who practiced this rotation have accomplished more in the last five years than those who did not. There was more uniformity in the amount and variety of crops they produced; they accomplished more per man and per horse; they had better crop yields; they made more money.

The suggestion that this crop rotation be more generally practiced is made with a full realization of certain difficulties encountered in planning and carrying out such a system in this area. The broken character of the surface renders it difficult to arrange the desired number of fields of the same size to be used in the crop-rotation system. However, the surface features of the farms on which rotation systems have been established were no more favorable for this arrangement than are those of many of the farms lacking a definite rotation system. It is largely a question of a farmer realizing the importance of such a system. When this is once realized, by careful planning the fields of most farms can be arranged more favorably for establishing a definite crop-rotation system.

RECEIPTS.

The farm receipts in this area amounted to \$925 per farm for the five-year average, ranging from \$796 in 1913 to \$1,112 in 1916. (See Table I). There was considerable diversity in the sources of income, as shown by the percentage distribution of the receipts in Table III. The sales of live stock, together with such products as butter, cream, eggs, and wool, amounted to \$672 per farm, while the sales of crops amounted to \$165 per farm. Approximately, then, almost three-fourths of the receipts were from live stock and its products.

TABLE III.—Percentage distribution of receipts on 25 farms over a period of 5 years, 1912–1916 (Palmer Township, Washington County, Ohio).

Item.	1912	1913	1914	1915	1916	5-year average.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Crop receipts.....	26	10	16	20	16	18
Live stock receipts:						
Cattle ^a	19	27	23	28	31	26
Horses and colts.....	4	1	3	1	1	2
Sheep and wool.....	20	12	13	12	12	14
Hogs.....	7	13	16	13	13	12
Poultry and eggs.....	17	20	20	18	18	19
Total stock receipts.....	67	73	75	72	75	73
Miscellaneous receipts.....	7	17	9	8	9	9

^a Includes sale of dairy products.

CATTLE.

Most of the cattle in this area represented good types of the beef breeds. A number of the bulls were pure-bred Herefords or Short-horns, and some pure-bred cows were kept on a few farms. More receipts were obtained from cattle than from any other source. For the five-year average, cattle receipts amounted to \$240 per farm, increasing from \$168 in 1912 to \$339 in 1916. This increase of over 100 per cent in the cattle receipts is attributed to an increase in the

number of cattle (Tables IX and XIII), higher prices received (Table XI), and the growth of dairying (Table IV).

Dairying has always been but a small part of the farm business in this area, and for the period covered by this study receipts from the sale of dairy products amounted annually to but \$53 per farm, or less than one-fourth of the total cattle receipts. However, a noticeable increase in dairying has taken place during the five-year period. In 1912 the dairy receipts for none of the 25 farms exceeded \$100, while in 1916 they amounted to over \$100 for seven farms.

In 1912 the dairy receipts on these farms amounted to \$27 per farm, and were entirely from the sale of butter. The following year one farm began shipping cream. In 1914 a cream station was operated



FIG. 8.—Cattle sales, including small quantities of butter and cream, comprise one-fourth of all the farm receipts. The yearling steers and heifers shown above are to be sold the following year. They represent the prevalent type of cattle raised in the area.

at Waterford, and in the spring of 1915 a creamery was started at Vincent. Though there has been no rapid advance in dairying in Palmer Township, the selling of cream stimulated it until in 1916 the sale of dairy products amounted to \$77 per farm. This growth is shown by years in Table IV.

TABLE IV.—*Growth in dairying on 25 farms, 1912-1916 (Palmer Township, Washington County, Ohio).*

Item.	1912	1913	1914	1915	1916
Receipts from dairy products (per farm).....	\$27	\$38	\$50	\$70	\$77
Per cent of total farm receipts from dairy products...	3	5	5	8	7
Per cent of dairy receipts from cream ^a		14	30	65	68

^a To include all dairy products except butter.

The percentage of the total farm receipts from the sale of dairy products was less in 1916 than in 1915, not because the dairy receipts were less in 1916, but because the receipts from other sources were somewhat more.

POULTRY AND EGGS.

All farms kept poultry, and the sales of poultry and eggs constituted the second highest source of income, amounting to \$169 per farm,

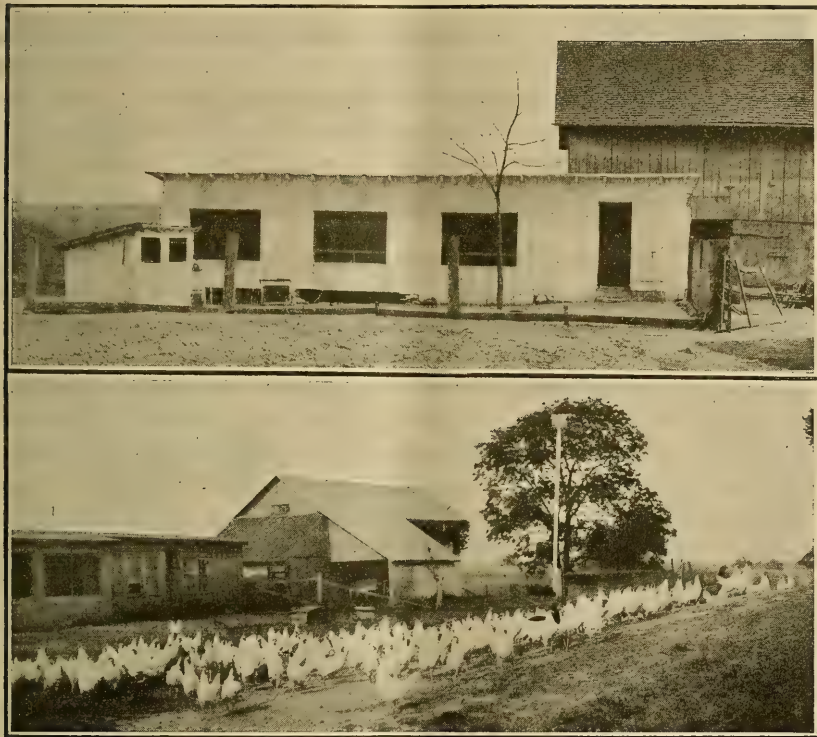


FIG. 9.—In Palmer Township the sales of poultry and eggs have amounted to more than those from any other source except cattle. The poultry house shown in the upper picture is typical of those on many of the farms that receive over \$200 per year from the sale of poultry and eggs. It was built in 1914, with a total cash outlay of \$63 for material, and accommodates 130 hens during the winter. The flock of White Leghorns in the lower picture is one of the flocks from which over \$200 worth of poultry and eggs are sold each year.

of which total \$138 was from the sale of eggs. Chickens represented 97.5 per cent of all poultry kept, and the sales of chickens and eggs amounted to \$167 per farm, or 99 per cent of all poultry and egg receipts. On 18 of the farms all of the poultry was chickens. The prevailing breeds were the White and Brown Leghorns, although Barred Plymouth Rocks and Rhode Island Reds were also kept on some farms. Turkeys were reported on five farms and ducks or guineas on occasional farms. (See fig. 9.)

Receipts from poultry and eggs varied on individual farms from \$61 to over \$300. Of the 25 farms 8 received less than \$100 annually from this source, 7 received from \$100 to \$200, and 10 received over \$200. The number of chickens kept varied from 60 to 330, with an average of 164 per farm. Table V shows the average receipts per farm and per hen from the different-sized flocks. Flocks of 201 to 330 hens, with such returns as shown in the table, did not of themselves make high labor incomes for their owners, but the sales of chickens and eggs from these flocks constituted 23 per cent of the farm receipts, and the farmers made fair labor incomes. The data do not indicate that a flock of this size is the maximum-sized flock that may profitably be kept in this area, for the flocks of over 200 hens brought higher returns per hen than those of fewer than 200, and their owners realized considerably higher labor incomes. The magnitude of the poultry enterprise may well be increased on practically all farms of the township. For those who at present have small flocks it may not be desirable rapidly to increase their flocks, but they could well be gradually increased as experience and skill in the management of poultry flocks is acquired, until every farm realizes over \$200 annually from the sales of chickens and eggs. In fact, the flocks in Palmer Township could safely be increased so that in a few years the income from poultry and eggs would be doubled. The poultry enterprise was the source of the largest item of income on nine of the farms and of second largest on six farms. In addition to this enterprise being one of the leading sources of income, it is further commendable because its receipts are distributed throughout the year. They are greatest during the spring and early summer months, but there is not a month of the year without some receipts from this source. Poultry is also of considerable importance as a source of the home food supply.

TABLE V.—*Relation of number of chickens kept per farm to receipts per hen on 25 farms (Palmer Township, Washington County, Ohio.).*

Classification of farms.	Number of flocks.	Average number of chickens per farm.	Receipts from chickens and eggs per farm.	Receipts per hen.
Farms keeping—				
60-100 chickens.....	6	88	\$82	\$0.93
101-200 chickens.....	14	156	157	1.01
201-330 chickens.....	5	274	295	1.08
All farms.....	25	164	167	1.02

As already pointed out, 40 per cent of the farms realized annually ove \$200 from poultry and eggs, and this was accomplished without serious interference with the other farm operations.

In connection with the poultry enterprise, data in addition to those obtained in the regular farm management survey were gathered on a number of farms. In these cases some member of the family kept a record of the flock for the farm year 1913. The data for 11 farm flocks show that 83 per cent of the yearly egg production was sold, 3 per cent was used for hatching, and 14 per cent for household purposes. These flocks varied in size from under 100 to over 200 hens, and the annual production was 86 eggs per hen. Approximately one-half of the yearly production was during the three months March, April, and May. The lowest egg production was during November, with an increase each succeeding month until April, the month of highest production. After April there was a decrease each succeeding month until the end of the farm year (Oct. 31). The highest price received for eggs in that year was 38 cents per dozen in November, the lowest 15 cents per dozen in April. Figure 10 shows graphically a comparison of the monthly egg production and the prices received each month.

SHEEP AND WOOL.

Sheep were kept on 23 of the 25 farms, the number in the flocks varying from 1 to 146.

For the five-year period sheep, including wool, brought the third highest item of income. Receipts from this source amounted to \$128 per farm, or about one-seventh of the total. The greater part of the receipts from the sheep enterprise came through the sale of wool, which amounted to \$84 per farm. All sheep reported were of the fine-wool breeds. (See fig. 11.)

Returns from sheep were low when compared with returns from other classes of stock. The receipts for each 10 head of sheep were \$34.30, while those for each cow, or her equivalent in other cattle, were \$31.20, for each 5 hogs \$53.90, for each 100 chickens \$99.80, and for each 2 colts \$48.10.

The actual sales per animal unit from cattle were less than from sheep, but they did not include the value of any products used by the family. Data obtained from a number of these farms show that cattle furnished more toward the family living than any other class

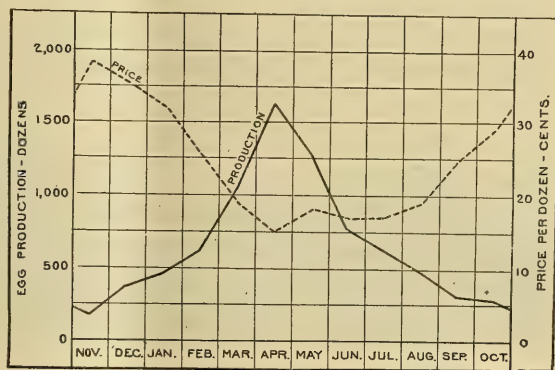


FIG. 10.—Monthly egg production and prices received on farms studied.

of stock, and that when proper credit was given for this, the returns per animal unit from sheep were lower than those from any other class of stock.

This does not mean that sheep were unprofitable on all the farms. In reality they were profitable on some farms. Profit or lack of profit from sheep seemed due not so much to the sheep themselves as to different practices of farmers in handling them. They have been kept mainly for wool production, and on some farms were kept for several years with no other returns than the wool they produced.

A few farmers have been following the practice of keeping flocks of ewes that produced lambs in April or May. The better ewe lambs were retained, and the remainder sold, either in the fall when about 6 or 7 months old or after shearing when about 1 year old. Over one-fourth of the farmers that kept sheep have followed this practice to



FIG. 11.—Most of the farms had flocks of fine-wooled sheep, which grazed on the hill-sides during the pasture season. Flocks of ewes that raised lambs which were sold at 12 to 14 months of age returned much higher receipts per head than flocks kept only for the wool they produced.

some extent and all report favorably. Table VI shows the number of sheep kept per farm, the per cent of the sheep receipts that were from wool, and the receipts per sheep for the farms that have practiced selling lambs and for those that have not. The farmers who sold lambs received \$1.12 per head more from their sheep than those who did not.¹

TABLE VI.—Receipts per sheep for farms that practice selling lambs and for farms that do not (Palmer Township, Washington County, Ohio).

Farm group.	Number of farms.	Number of sheep per farm.	Per cent receipts from wool.	Receipts per sheep.
Farms selling lambs.....	7	40	60	\$4.40
Farms not selling lambs.....	16	33	69	3.28

¹ Sheep and wool both brought higher prices in 1917 than during the years covered by this study, and with the higher prices the farmers selling lambs still obtained higher receipts per head than those not selling them.

HOGS.

The receipts from hogs for the five-year period averaged \$118 per farm, or one-eighth of the total receipts, and varied from \$61 per farm in 1912 to \$154 in 1914. A few of the farmers bought pigs for growing their own pork supply, but most of them kept one or two brood sows. Sixteen per cent of the farmers sold no hogs, 44 per cent sold from \$42 to \$100 worth, and 40 per cent sold over \$100 worth. The production of hogs in this locality is necessarily limited because of the small amount of corn produced.

HORSES AND COLTS.

Horses are kept on these farms primarily for the work they do, and but few of the mares raise colts. Most of these colts, after growing into horses, are either sold or replace horses that have died or that have been sold. The receipts from horses and colts were therefore low, amounting to only \$28 per farm, or about 2 per cent of the total receipts.

CROP SALES.

The total crop sales amounted to \$165 per farm, or \$4 less than the sales of poultry and eggs.

Almost all crops produced were represented in the crop sales, but over seven-eighths of the total crop sales were from the four crops, wheat, hay, fruit, and corn, named in the order of their importance. The remaining one-eighth of the crop receipts amounted to \$18 per farm, and included the sale of clover seed, potatoes, oats, rye, soy beans, straw, fodder, cider, and vinegar.

MISCELLANEOUS RECEIPTS.

In addition to selling live stock, butter, cream, eggs, wool, and farm crops, many of the farmers received some money from the sale of lumber, posts, wood, or shackle poles, for the rent of pasture or farm buildings, for the use of part of the farm equipment, such as the farm machinery or the farm team, and for part of their own labor or time. These have all been considered receipts of the farm business and designated "miscellaneous receipts." They totaled \$81 per farm, and made up a little less than one-tenth of the total farm receipts. Most of these receipts were for work done off the farms, either by the farmers alone or with their teams, and included such work as day labor on other farms, official work, road work, hauling coal, and moving oil rigs.

EXPENSES.

All costs in connection with operating the farm business above those of interest on investment and value of the farmer's own labor

are included in the farm expense. For the five-year period these averaged \$419 per farm and amounted to 45 per cent, or almost one-half of the farm receipts. These expenses, with the exception of \$87, the value of the unpaid family labor, all represent money paid out. The farm expenses for the different years were shown in Table I. For three of the five years they approximated the five-year average, for one year they were about 10 per cent below the average, and for 1916 they were 9 per cent above the average. For the purpose of this discussion the expenses have been grouped in six classes, viz, labor, repairs and depreciation, feed, seeds and fertilizer, taxes and insurance, and miscellaneous. The proportion each class represented of the total expenses each year and for the five-year average is shown in figure 12.

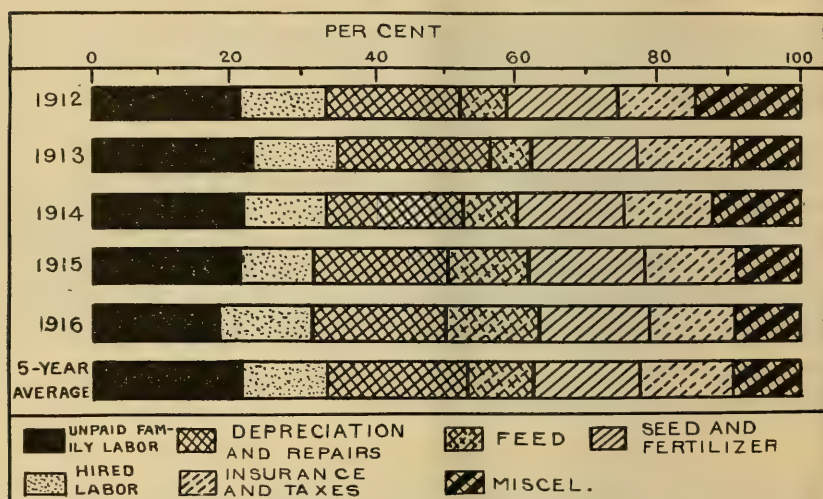


FIG. 12.—Distribution of expenses, 25 farms, Palmer Township, Washington County, Ohio.

LABOR.

The value of all labor on the farms, except that performed by the farmer himself, was \$136 per farm, or about one-third of the total expenses. Of this amount, \$87 was for 3.6 months of unpaid family labor and \$49 for 1.6 months of hired labor. About 90 per cent of the labor was performed by the farmers and their families, with a comparatively low cash expense for labor. One farmer kept a hand throughout the year, another had a hand for six months of the year and four kept hands for a few months during the summer. In all, six farmers each had a regular hired hand for part or all of the year and with a total expense of \$554. for regular hired labor. Almost as much of the labor hired, however, was for hands for a single day or a few days at a time now and then during rush periods. More or

less extra labor of this sort was hired on 24 of the farms, at a total cost of \$489.

The labor expense was practically the same for the first four years, and in 1916 it was 4 per cent above the five-year average.

REPAIRS AND DEPRECIATION.

Expenses for repairs and depreciation included repairs on machinery, dwellings, other buildings, and fences, and depreciation on dwellings, other buildings, and machinery. These were all considered cash expenses. The expenses for repairing machinery, buildings, and fences represented only those actually paid out, and did not include the value of any repairs made by the farmer himself or of any repair material furnished from the farm. The expense for depreciation of machinery and buildings was equivalent to a cash expense. While we do not think of money as actually paid out for depreciation, yet it was paid for new machinery to replace that worn out, for replacing old buildings so far gone that others were built in their stead, and for such extensive repairs to buildings as would avoid the necessity of replacing them for several years.

The annual expense for repairs and depreciation amounted to \$81 per farm, or 20 per cent of the total farm expenses. The expense for depreciation was about twice that of repairs.

The annual expense of all farms for repair of machinery was \$4 per farm, or slightly over 1 per cent of the inventory value of the machinery; that for depreciation was \$25 per farm, or nearly 8 per cent of the inventory value. The total annual cost for upkeep of machinery was \$29 per farm, or 9 per cent of the inventory value. New machinery was bought to the amount of \$37 per farm.

For all farms the annual expense for keeping the dwelling in repair was \$6 per farm and that for depreciation was \$10. The total annual expense for repairs and depreciation of the dwellings was \$16 per farm, or $1\frac{2}{3}$ per cent of the value of the dwellings.

The expense for repair and depreciation of the other farm buildings was greater than that for the dwellings. The average annual repair expense was \$7 per farm and that of depreciation was \$18. The annual repair and depreciation expense together were \$25 per farm, or just a little over 3 per cent of the value of the buildings.

The expense for fence repair includes not only slight cash expenses for repairing fences but also the cash outlay for new fencing when it is to replace that worn out. The average annual expense for keeping fences in repair on all these farms was \$11 per farm, or 7 cents per acre. The reason for such a low expense for fence repair in this area may be readily seen from figure 3 (p. 7). With so many rail fences most of the fencing material was furnished by the farm without cash outlay.

FEED.

The annual expense for feed bought on all these farms was \$38 per farm, or nearly 10 per cent of the total farm expenses. For all farms about one-twelfth of the feed expense was for roughage, mainly hay, and eleven-twelfths for concentrates—corn, middlings, bran, oil meal, cottonseed meal, tankage, poultry feeds, and in a few instances oats and wheat.

FERTILIZER AND SEED.

Expenses for fertilizer and seeds were \$65 per farm, or about one-sixth of the total farm expense. Of this, \$42 was for fertilizer and \$23 for seed.

Most of the fertilizer used in Palmer Township was 14 per cent or 16 per cent acid phosphate. On a few farms steamed bone was the source of their phosphoric-acid supply, and occasionally farmers used both of these fertilizers. Some farmers used ready-mixed goods, with analysis of something like 2-8-2. Some farmers have practiced mixing fertilizers to some extent, generally using nitrate of soda, acid phosphate, and muriate of potash. Most farmers seemed to think that acid phosphate was the preferable form in which to get the supply of phosphoric acid. The expense for fertilizer included that for lime, which amounted to only a few dollars per farm.

Most of the seed expense was for clover and grass seeds. As shown on page 23, very few of these farms produced all the clover seed used on them, and the production of timothy seed received even less attention than that of clover. In reality, practically all farmers bought all the timothy seed they used. In addition to the purchase of clover and timothy seed, several farmers bought bluegrass or redtop. Of course, a farmer occasionally bought seed corn, wheat, oats, or rye, but the expense for such seeds was of little importance when compared with that for clover and grass seeds. The annual seed expense for all these farms was 50 cents per crop acre.

INSURANCE AND TAXES.

The insurance carried on buildings and contents and live stock cost \$5 per farm and varied from \$3 to \$6 for different years. Practically all the insurance was carried in mutual companies.

Taxes amounted to \$48 per farm, increasing from \$45 in 1912 to \$51 in 1916. The combined expense for insurance and taxes was \$53 per farm, or one-eighth of all farm expenses.

MISCELLANEOUS EXPENSES.

All farm expenses not already discussed have been combined under "miscellaneous expenses." In this group were included all such

expenses as feed grinding, silo filling, fodder shredding, horseshoeing, breeding fees, veterinary, spray material, twine, thrashing, clover hulling, baling, hire of machinery, fuel and oil for farm work, rented pasture, and team work. Not one of these items of expense amounted to 2 per cent of the farm expenses, and combined they amounted to \$39 per farm, or nearly one-tenth of all farm expenses. More than one-half of this amount was for the four items of horse-shoeing, breeding fees, thrashing, and baling.

THE INVESTMENT.

The farm investment consists of real estate and working capital. The real-estate investment is separated into land, dwelling, and other buildings, and the working capital into live stock, machinery, feed and supplies, and cash for operating the farm business. For the five-year period the investment averaged \$6,378 per farm, increasing from \$6,087 in 1912 to \$6,639 in 1916. The average real-estate investment for the five-year period was \$4,773 per farm, or three-fourths of the total investment; the working capital was \$1,605 per farm, or one-fourth of the farm investment.

The percentage distribution of the farm investment in this area from 1912 to 1916, inclusive, together with the five-year average, is shown in Table VII.

TABLE VII.—Percentage distribution of investment on 25 farms over a period of five years, 1912–1916 (Palmer Township, Washington County, Ohio).

Item.	1912	1913	1914	1915	1916	5-year average.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Land.....	48	47	45	45	44	46
Dwelling.....	16	16	16	16	16	16
Other buildings.....	14	13	13	13	13	13
Real estate.....	78	76	74	74	73	75
Live stock.....	13	15	16	16	17	15
Machinery.....	5	5	5	5	5	5
Feed and supplies.....	3	3	4	4	4	4
Cash.....	1	1	1	1	1	1
Working capital.....	22	24	26	26	27	25

REAL ESTATE.

The greater part of the real-estate investment was in land, this including all farm improvements except buildings. The five-year average investment in land was \$2,912 per farm, or less than one-half of the farm investment.

The dwelling as a rule represented good and substantial types of buildings. As would be expected in any farming area that had been settled for more than 100 years, the dwellings here were of widely

varying ages—some at least 75 years old, while two were built during the five-year period covered by this study. Many of the dwellings were from a third to half a century old and parts of some of them had been built originally of logs. However, most of these have been so remodeled that it would be difficult for the casual observer to distinguish them from the more recent frame dwellings. Brick dwellings were found on but two of the farms studied. Aside from these and the few that have been remodeled from old log houses, the dwell-

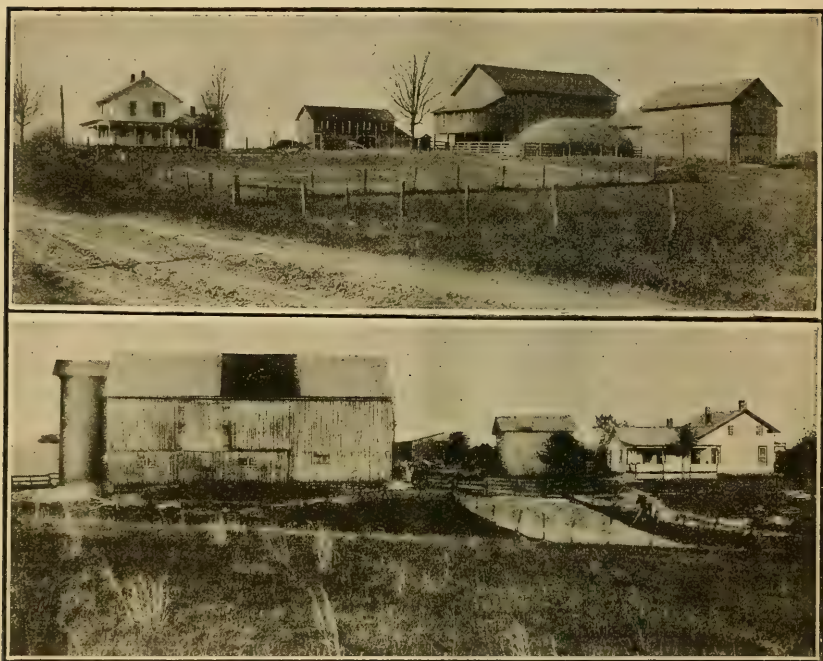


FIG. 13.—Two Palmer Township farmsteads. The dwelling shown above is one of the 27 ranging in value from \$1,000 to \$1,800; the one below is one of the 31 with a range of from \$400 to \$1,000 in value. The other buildings shown above are representative of those with values ranging from \$1,000 to \$1,800; those below are representative of the other buildings ranging from \$400 to \$1,000 in value.

ings were of frame structure. Most of the dwellings were in good repair and well painted. Several have slate roofs. Many of the farmers evidenced considerable pride in having their homesteads appear neat and attractive. (See fig. 13.)

The average value of the dwellings was \$1,014, with variations from \$300 to \$3,500. The dwellings on one-half of the farms were valued at less than \$1,000 each, on one-third of the farms at from \$1,000 to \$1,400 each, and on one-sixth of the farms at \$1,500 or more each.

All buildings aside from the farm dwellings were listed as "other buildings." The main part of the investment in this class of build-

ings was in barns, although many farm buildings, such as sheep stables, wagon houses, corn cribs, granaries, poultry houses, and an occasional tenant house, were included with the barns. The investment in this class of buildings was \$847 per farm or somewhat less than that in dwellings. It represented about one-eighth of the farm investment.

WORKING CAPITAL.

The investment in live stock represented more than one-half of the working capital. For the five-year average it amounted to \$982 per farm, or about one-sixth of the farm investment.

The investment in machinery was 5 per cent of the farm investment and amounted to \$319 per farm, or \$7 for each acre of crops.

Feed and supplies included the value of all crops on hand at the beginning of the year that were intended to be fed on the farms or used as seed. It consisted principally of corn and hay, although wheat, oats, and timothy, clover, and soy-bean seed were also listed under feed and supplies. This investment amounted to \$247 per farm, or less than 4 per cent of the total farm investment.

The average amount of cash carried on hand for use in the farm business was \$57 per farm, and represented a little less than 1 per cent of the total investment.

With a gradual increase in the farm investment from 1912 to 1916, the percentage each item represented of the total investment would have been uniform from year to year if the several items had increased in the same proportion. Increase in the investment in dwellings, other buildings, machinery, feed and supplies, and in the cash used for operating the farms kept pace with the increase of the total farm investment, and shows practically the same percentage of the total investment each year. The investment in land, however, remaining about the same throughout the period, shows a yearly decrease in its percentage of the total investment. The investment in live stock, increasing more rapidly than any other item of the investment, shows a yearly increase in the percentage of the farm investment.

YIELD PER ACRE OF THE MORE IMPORTANT CROPS.

The yield per acre of the important crops over the five-year period, as shown in Table VIII, was much greater than the acreage variation of these crops. In 1912, 1914, and 1915 the yields of corn were practically the same, while 1913 was decidedly the best corn year and 1916 the poorest.

Wheat gave an average yield in 1912, with low yields in 1913 and 1916 and with good yields in 1914 and 1915.

Hay yielded $1\frac{1}{2}$ tons per acre in 1912 and 1916, the best two hay years, while in 1914, the poorest hay year, the yield was slightly less than 1 ton.

For each crop there were good years and poor years, but in no year were all crops good or all crops poor. The year 1912 had average corn and wheat yields and good oat and hay yields; 1913 had good corn yield, average oat yield, and low wheat and hay yields; 1914 had an average corn yield, good wheat yield, and low oat and hay yields; 1915 had average yields of corn, oats, and hay and a good wheat yield; in 1916 the yields of corn, wheat, and oats were low, while that of hay was good. There was no year without some good crop, so that each year had a fair amount of feed for the stock. The crop yields, as a whole, were highest in 1912 and lowest in 1913.

TABLE VIII.—Yield per acre of the principal crops on 25 farms over a period of five years, 1912-1916 (Palmer Township, Washington County, Ohio).

Crop.	1912	1913	1914	1915	1916	Five-year average.
Corn.....bushels..	43	52	43	44	35	44
Wheat.....do....	14	9	18	18	11	14
Oats.....do....	34	31	25	28	24	29
Hay.....tons.....	1.5	1.1	.9	1.2	1.5	1.2

The reason assigned for the poor wheat crop in 1913 was injury from Hessian fly and for the poor crop in 1916, winter killing. The reason for yearly variation in the yields of corn and hay may best be found in the rainfall diagram on page 8. It is generally considered by those who have made correlations between rainfall and corn yields that the amount of rainfall during the month of July greatly influences the corn yields. July, 1913, had greater rainfall than any other July of the five-year period, and it was the year with best corn yields. On the other hand, July, 1916, had less rainfall than any other July of the period, and 1916 was the year with lowest corn yields. July, 1914, had little rainfall, but the season being the latest of any of the five years, the rains of early August sufficiently offset the July drought so that the corn yield for that year was about normal.

The total rainfall during the months March to June, inclusive, or during the growing season for hay, was greatest in 1912 and 1916, the two years with best hay yields, and least in 1914, the year with lowest hay yields.

THE KIND AND AMOUNT OF LIVE STOCK.

The total amount of live stock kept each year is shown in Table IX, together with the percentage each kind represented of the total productive live stock. There was a gradual yearly increase in the

amount of stock kept on these farms, with the single exception of 1915, when it was slightly less than in 1914. While this increase in stock was only 2.6 animal units from 1912 to 1916, yet it was an increase of 20 per cent, and, when considered in connection with the rising prices of animal products, was quite significant in increasing the labor income.

TABLE IX.—*Relative amount of live stock kept on 25 farms over a period of five years, 1912-1916 (Palmer Township, Washington County, Ohio).*

Distribution of animal units.	1912	1913	1914	1915	1916
Total productive animal units per farm.....	13.5	14.4	15.3	14.9	16.1
Percentage of total productive animal units in—					
Cattle.....	41	45	49	53	58
Horses and colts ^a	4	4	4	4	4
Sheep.....	35	28	21	19	17
Hogs.....	9	11	15	13	10
Poultry.....	11	12	11	11	11

^a Does not include work stock.

With a gradual increase in the amount of stock kept there were also changes in the number of stock of the different kinds, especially in cattle and sheep. The number of cattle increased 68 per cent from 1912 to 1916 and the number of sheep decreased 58 per cent during the same period. Both the increase of cattle and the decrease of sheep represented gradual changes. There were more cattle and fewer sheep each succeeding year.

THE AMOUNT OF FEED REQUIRED FOR LIVE STOCK.

The feeds produced on the farms for live-stock consumption in this area were corn, small grains, and hay. While a small quantity of feed was bought, the bulk of the feed, exclusive of pasture, was derived from these crops. To determine the relative importance of these crops as sources of feed, and the amount of feed required per animal unit per annum for the live stock kept on the farms in this area, a system was used for reducing the feeds to a common standard. This standard, known as a feed unit, represents the expression of all feeds consumed when compared with the feeding value of a pound of corn. In the footnote under Table X is given the relative value of each feed used on these farms.

The percentage of the total feed units derived from each kind of feed that has been fed by 25 farmers during each year of the five-year period and the average number of feed units they fed per animal unit are given in Table X. This table may be practically applied in two ways:

(1) With a given number of stock one can readily approximate the total quantity of feed that will be required, the proportion of concentrates and of roughage.

(2) With given quantities of various feeds, one can approximate the number of stock he will be able to carry, and determine if the feed is fairly well apportioned between concentrates and roughage.

For these purposes the average over the five-year period should be used for the standard, while the extremes in the different years may be used to indicate possible variations.

TABLE X.—*Percentage of total feed units from each kind of feed and the number of feed units per animal unit on 25 farms over a period of 5 years, 1912-1916 (Palmer Township, Washington County, Ohio).*

Distribution of feed units.	1912	1913	1914	1915	1916	Five-year average.
Percentage of total feed units <i>a</i> from—						
Corn (grain)	47	42	46	43	36	42
Wheat	10	7	6	5	7	7
Oats	3	2	1	1	1	2
Rye			(b)	1	(b)	(b)
Bought feed	4	3	4	6	7	5
Corn fodder (stover)	11	9	9	9	7	9
Corn silage		4	4	4	10	5
Hay	25	33	30	31	32	30
Concentrates, per cent of total feed units ..	64	54	57	56	51	56
Roughage, per cent of total feed units	36	46	43	44	49	44
Number of feed units per animal unit <i>c</i>	2,365	2,745	2,846	2,711	2,698	2,673
Number of acres of pasture per animal unit <i>d</i>	5.2	5.0	4.9	4.7	4.5	4.9

a A "feed unit" represents the feed value of a pound of corn or its equivalent.

1 bushel corn=56 feed units.

1 bushel wheat=60 feed units.

1 bushel oats=29.1 feed units.

1 bushel rye=56 feed units.

1 ton bought feed=2,000 feed units.

1 ton fodder (stover)=500 feed units.

1 ton silage=333 feed units.

1 ton hay=800 feed units.

Feed units computed according to table in Wisconsin Circular No. 37, June, 1912.

b Less than one-half of 1 per cent.

c In calculating the number of feed units per animal unit, straw when used as feed was not considered, neither was pasture. The feed value of pasture is generally placed at 8 to 10 feed units per animal unit daily.

d Includes animal units for work stock but not for poultry.

The following example will serve as an illustration of the first way in which the table may be applied:

A farmer keeps 6 cows, 1 bull, 3 horses, 50 ewes, 2 brood sows, and 250 chickens. He will raise or feed out 1 heifer, 4 steers, 6 calves, 50 lambs, 40 hogs, and 120 chickens. He wishes to determine the quantity of feed required. The above stock is the equivalent of 39 mature horses or cows. With 2,673 feed units required for each animal, the total feed requirement is 104,247 feed units. The concentrates required for feed, as shown in this table, are 56 per cent of this total, or 58,378 feed units, which is the equivalent of 1,042 bushels of corn. The roughage required is 44 per cent of the total, or 45,869 feed units, the equivalent of 57 tons of hay. Were corn the only concentrate used, and hay the only roughage, these would be the approximate quantities required. But in this area wheat, rye, oats, and various bought feeds, such as bran, middlings, oil meal, cottonseed meal, and tankage, are also sources of concentrate feeds, and

silage and corn stover as well as hay are used for roughage. As shown in Table X, the number of feed units of corn is 42 per cent of the total, or 43,784, and this divided by 56, which represents the feed units value of a bushel of corn, is 782, or the number of bushels of corn required. After making a similar calculation for each kind of feed, the following approximate feed requirements for the above stock are obtained:

Concentrates.		Roughage.	
Corn	bushels-- 782	Corn fodder (stover)	tons-- 19
Wheat	do-- 122	Silage	do-- 16
Oats	do-- 72	Mixed hay	do-- 39
Bought feed	tons-- 2.6		

To illustrate the second way in which the table may be applied:

A farmer has for feeding, 500 bushels corn, 50 bushels wheat, 12 tons corn stover, and 23 tons mixed hay. He wishes to determine the amount of stock he can carry. The corn and wheat have the feed value of 31,000 feed units ($500 \times 56 + 50 \times 60 = 31,000$), and the corn stover and hay that of 24,400 feed units ($12 \times 500 + 23 \times 800 = 24,400$), or a total of 55,400 feed units. The total divided by 2,673 equals 20+, or the approximate number of animal units he can expect to carry without the purchase of additional feed. The concentrates in this case are 56 per cent of the total feed units and the roughage 44 per cent, or in the same proportion as the average for the 25 farms over the 5-year period.

On these farms most of the stock were on pasture during the pasture season, but the pasture consumed has not been included in the feed requirements. The feed value of pasture is generally placed at 8 to 10 feed units daily per animal unit. Occasionally some straw was fed, but the quantity was very small, and it was not included in calculating the feed requirements.

THE SOURCES OF SUPPLY AND DEATH RATE FOR THE DIFFERENT CLASSES OF LIVE STOCK.

Since live stock with its products is the source of so large a part of the income in this area, some data as to the sources of supply of the different classes of stock, together with the losses, are presented here. These data are for the 25 farms over the five-year period, and in the case of live-stock losses represent what ordinarily may be expected.

The work stock consisted almost entirely of horses. Some of the farmers kept the same work horses throughout the five-year period; others changed all their horses, and still others changed some of them. Fifteen per cent of the work horses were changed each year, three-fourths of which were sold and one-fourth of which died. This indicates that the work horses are kept on the same farms for an average of $6\frac{2}{3}$ years. The horses disposed of were replaced by colts and by purchases—almost an equal number from each source. The

death rate for work horses was 4.2 per cent. The rate of depreciation for all work stock kept on these 25 farms during the five years was 4.1 per cent annually. Twice as many colts were foaled during this period as there were horses that died, and 30 per cent more horses were sold than bought. The number of colts raised was more than sufficient to meet the death rate for the horses, although the latter might have been somewhat higher were it not that several horses were replaced before they became very old.

Cows were replaced just about as frequently as horses, the percentage of the total number disposed of annually being 14.7 per cent, indicating that the average time cows are kept on the same farm was 6.9 years. The death rate for cows was 1.4 per cent, or much lower than for horses. One-fourth of the cows were replaced by purchase and three-fourths by heifers from the home farm. About one-half of the heifers raised became cows and one-half were sold as beef stock. For the five-year period the average annual production of calves was 89 per cent of the number of cows kept. About 85 per cent of the calves were kept until they were over a year old. Some were sold as yearlings, but the greater number, excepting the heifers that became cows, were carried over another year and sold as 2-year-olds. For all cattle the death rate was 2.9 per cent, of which one-half were calves under 1 year old.

The main source of the sheep supply for each farm was lambs raised on the farm. There was some buying and selling of sheep among the farmers, but 80 per cent of the sheep were raised. Sheep losses were greater than those of any other class of stock, the death rate being 7.7 per cent annually. The loss from dogs was insignificant when compared with that from other causes. The greater part of the losses were caused by the stomach worm.

Almost 90 per cent of the hogs fed out on these farms were farrowed on the farms on which they were fed. The sows usually produced two litters a year, and the average number of pigs was 10.5 per sow annually. The death rate among sows was 6 per cent, and that for all hogs 4.8 per cent.

FACTORS AFFECTING FARM PROFITS.

The profits from year to year for the farms in this area are shown in Table I, on page 12. In 1912, 1914, and 1915 the profits were about normal, being within 20 per cent of the five-year average. The year 1913 was the poorest year and 1916 the best, whether the profits be determined by the labor income or by the per cent received on the investment. The labor income in 1913 was 40 per cent below the five-year average, and in 1916 it was 70 per cent above the average, or almost three times that of the poorest year. These were also the years with respectively the least and the greatest amounts of money

available for the farmers and their families, and when the least and the greatest reductions were made in the farm indebtedness.

The year of least profits was the year with lowest wheat yields; the apple crop was also almost a failure. Wool sold lower, and the price of sheep was lower than in any other year, except 1914. Had the sales of these four items amounted to as much as the five-year average, the profits in 1913 would have reached those for the five-year average.

The main factors contributing to the greater profits of 1916 were the higher prices received for most farm products and the greater quantities sold of a few products. All classes of live stock, as well as eggs and wool, brought higher prices in 1916 than in any other year. All crops, except hay and clover seed, sold higher in 1916 than the five-year average, although a few crops brought higher prices some other years than in 1916. (See Table XI.)

TABLE XI.—*Prices received for farm products on 25 farms over a period of five years, 1912-1916 (Palmer Township, Washington County, Ohio).*

Product.	Unit.	1912	1913	1914	1915	1916	Five-year average.
Corn.....	Bushel..	\$0.46	\$0.76	\$0.76	\$0.72	\$0.81	\$0.70
Wheat.....	do.....	.98	.97	1.19	1.15	1.52	1.16
Oats.....	do.....	.35	.64	.....	.45	.50	.48
Rye.....	do.....	.62	1.07	1.00	.....	.....	.90
Hay.....	Ton.....	11.38	13.73	14.67	11.81	8.75	12.07
Potatoes.....	Bushel..	.59	1.00	1.50	.51	1.54	1.03
Clover seed.....	do.....	12.00	7.00	9.33	10.34	9.10	9.55
Apples.....	Barrel..	1.40	1.00	1.05	1.44	1.35	1.25
Eggs.....	Dozen..	.19	.19	.19	.19	.22	.20
Wool.....	Pound..	.23	.20	.25	.26	.31	.25
Cattle.....	Cwt.....	5.70	7.13	6.97	7.29	8.20	7.07
Sheep.....	Head....	3.22	3.00	2.97	4.30	4.56	3.61
Hogs.....	Cwt.....	6.52	8.20	8.10	6.60	8.50	7.58
Chickens.....	Head....	.42	.43	.41	.45	.48	.44

More cattle and clover seed were sold in 1916 than in any other year, a few more chickens than in any other year except in 1913, more hogs than in any other year except 1915, and more hay than in any other year except 1912. (See Tables XII, XIII.)

TABLE XII.—*Quantity of various farm products available for sale on 25 farms over a period of five years, 1912-1916 (Palmer Township, Washington County, Ohio.)*

Product.	Unit.	1912	1913	1914	1915	1916	Five-year average.
Corn.....	Bushels.	721	165	702	750	410	550
Wheat.....	do.....	1,421	386	878	2,080	812	1,115
Oats.....	do.....	124	109	.....	112	40	77
Rye.....	do.....	3	8	30	.....	.....	8
Hay.....	Tons.....	198	82	42	58	158	108
Potatoes.....	Bushels.	105	40	6	254	68	95
Clover seed.....	do.....	14	8	2	7	80	22
Apples.....	Barrels..	855	49	1,161	289	372	545
Eggs.....	Dozen..	15,695	16,190	19,468	18,121	17,400	17,373
Wool.....	Pounds..	10,483	10,115	7,348	7,900	8,374	8,444

The higher price for most 1916 products and the greater quantities or numbers of the products above mentioned sold both indicate that the labor income for 1916 should have exceeded that of former years even more than it did. This would be true except for two other factors, the increase in expense connected with operating the farm business and the decrease in the quantities or numbers of several farm products that were available for sale, both of which partly counteracted the higher prices received for most products.

The farm expenses in 1916 were greater than for any of the other years and 11 per cent more than the average for the five years. Most of this increase was for feed and hired labor. The expense for roughage feed in 1916 was slightly less than the five-year average, while that for concentrates was 72 per cent more than the average. The quantity of concentrate feeds bought was 56 per cent more and the price 10 per cent higher. The expense for hired labor in 1916 was 28 per cent more than for the average of the five years. The number of months of hired labor was 21 per cent more and the average wages 6 per cent higher.

Aside from hay and clover seed, the quantities of all crops sold were less in 1916 than the five-year average, and there were fewer sheep and less wool sold than the five-year average.

TABLE XIII.—*Number of young stock produced over a period of five years, 1912-1916, on 25 farms (Palmer Township, Washington County, Ohio.)*

Kind of stock.	1912	1913	1914	1915	1916	Five-year average.
Calves.....	68	69	77	85	91	78
Colts.....	6	2	6	6	7	5
Lambs.....	291	332	193	212	215	249
Pigs.....	184	232	320	318	273	265

With the higher prices, but smaller quantities sold, the sales of corn, wheat, oats, and apples in 1916 were each below the five-year average, while the smaller quantities of potatoes, wool, and sheep sold were so affected by the higher price received that the sales of each in 1916 were a little above the five-year average. The higher prices for these products were so counteracted by the quantities sold that the receipts from all of them in 1916 just equaled the five-year average receipts.

The only crop with decidedly higher receipts in 1916 than in preceding years was clover seed. It was a good clover-seed year, the production was over 300 per cent of the average, and the quantity sold 363 per cent. The price received was 5 per cent below the average and the sales amounted to \$29 per farm against a five-year average of \$8. However, the production of clover seed has been a minor en-

terprise in the township and can not be considered of great importance in affecting profits every year.

The sales of hay in 1916 were but \$7 per farm above the five-year average, the quantity sold being almost 50 per cent above the average and the price per ton 27 per cent below the average.

The 1916 crop receipts exceeded the five-year average 9 per cent, and the stock receipts, including dairy products, eggs, and wool, 25 per cent.

The single enterprise most affecting the greater 1916 profits was cattle, the receipts from which were \$99 (41 per cent) more than the five-year average, owing to higher prices and more cattle sold.

The variations from year to year in the yields of the different crops, in the numbers of the different classes of stock, and in the prices received for crops and stock were so distributed above and below the average as to produce no great variations in the labor income for three of the five years. In 1916 a sufficient number of these variations were above the average, and some of them were so much above the average as to produce a labor income considerably higher than the five-year average; while in 1913 they were sufficiently below the average to depress the labor income to 40 per cent below the average. These would indicate that in such an area as this, with a well-established and well-diversified system of farming, the variations in the quantities and prices of the several crops and kinds of stock above the average are so counteracted by those below the average as to produce little change in the labor income except when there is a general change in price levels, or a decidedly poor crop year.

A STUDY OF 73 FARMS BY SIZE AND QUALITY OF BUSINESS.

SIZE OF FARM BUSINESS.

It is a well-established principle that the size of business of whatever kind is one of the leading factors affecting its profits. The principle is as applicable to the farm business as to any other, and the data shown herein accord therewith. The number of acres of crops grown on the farms in this area was quite indicative of the comparative size of the business conducted on them, and it has been used in this bulletin as the measure of the size of the farm business. For this study in size all of the farms of the area from which usable records were obtained from one to five years, 73 in number, were arranged in three groups, based on the number of acres of crops raised. Each of the 18 farms in the first group produced 30 acres or less of crops, each of the 29 farms in the second group 31 to 45 acres, and each of the 26 farms in the third group over 45 acres.¹

¹ In addition to the 25 farms with five-year record, 48 other farms are here included—12 with two-year records, 12 with three-year records, and 12 with four-year records. The farms in each of these groups are almost equally divided among the different size groups.

A brief summary of the business conducted on these farms is presented in Table XIV. The data shown are for the average of the farms in the different-sized groups. Comparisons of these groups, one with another, will readily show that the size of the farm business is a very important factor in returning profits.

TABLE XIV.—*Summary of the farm business on 73 farms, by size of farm (crop area) (Palmer Township, Washington County, Ohio).*

[Except for number of farms, the figures are averages.]

Item.	30 crop- acres and under.	31 to 45 crop- acres.	Over 45 crop- acres.
Number of farms.....	18	29	26
Farm area.....acres.....	88	120	196
Crop area.....do.....	24	38	57
Number of productive animal units.....	8.2	11.0	18.6
Number of work stock.....	2.2	2.4	3
Crop yield per acre <i>a</i> per cent.....	96	97	106
Receipts per animal unit <i>a</i> do.....	104	98	100
Investment.....	\$3,817	\$4,860	\$7,807
Receipts.....	484	693	1,152
Expenses.....	232	307	513
Farm income.....	252	386	639
Interest on investment at 5 per cent.....	191	243	390
Labor income.....	61	143	249
Value of farmer's labor.....	\$236	\$278	\$287
Per cent on investment <i>b</i>	.4	2.2	4.5
Farm income.....	\$252	\$386	\$639
Value of unpaid family labor.....	47	60	98
Family income <i>c</i>	299	446	737
Interest paid on indebtedness.....	3	13	18
Amount available for family living.....	296	433	719

a Percentage of average for all farms.

b After deducting value of farmer's labor from farm income.

c The sum of farm income and value of unpaid family labor, or the amount available for family living had there been no interest to pay.

The farmers producing 45 acres or more of crops, on apparently no better land, used a little more fertilizer per crop acre and obtained better yields than the farmers obtained who produced a smaller acreage of crops.

On the small farms the receipts per animal unit were slightly more than on the large farms. This was mainly due to the proportionate numbers of the different kinds of stock on the farms of different size. Poultry represents a slightly higher percentage of the total productive live stock on the farms with 30 acres or less of crops and returned higher receipts than any other kind of live stock.

The proportion of the farm area in woodland and waste land, in pasture land and in crop land was quite uniform in the different size groups, but the proportion of the crop land in corn and in the small grains varied somewhat on the different-sized farms. On the farms with 30 acres or under of crops the corn acreage was somewhat more than the small-grain acreage; on the farms with 31 to 45 acres of crops the acreage of each was about equal; and on the farms with

over 45 acres of crops the acreage of small grains exceeded that of corn. That the farmers who did not raise over 30 acres of crops had a greater proportion of the crop area in corn and a smaller proportion in small grains than those who raised larger acreages of crops is quite natural, when the number of stock kept on the different groups of farms is considered in connection with the fact that practically all the feed consumed on these farms is produced on them and that the farmers consider corn the cheapest source of concentrates.

The average amount of stock kept on the farms with 30 acres or under of crops was $2\frac{1}{4}$ work horses, $2\frac{1}{2}$ cows, 4 head of young cattle, 13 sheep, 5 hogs, and 110 chickens. This complement of stock required concentrates equivalent to 280 bushels of corn and roughage equivalent to 12 tons of hay. With the average yields of corn and hay on this group of farms it would require 7 acres of corn and 11 acres of hay to produce the required amount of feed, and these correspond with the acreages actually raised. These farms had an average crop area of only 24 acres. With 18 acres used in aiming to grow enough feed for the stock, and with 2 acres in fruit, etc., it may readily be seen that only 4 acres, or a considerably smaller area than the acreage in corn, could be used in growing small grains.

The farmers with 31 to 45 acres of crops would require 10 acres of corn and 16 acres of hay to grow all the feed required for the stock they kept. They did grow 9 acres of corn and 17 acres of hay, or practically enough feed for their stock. With 26 acres used in growing corn and hay and 2 acres in fruit, etc., they had left of their total crop area of 38 acres 10 acres that were used in growing small grains.

The farmers that raised over 45 acres of crops would require 13 acres of corn and 22 acres of hay to produce all the feed required for the stock they kept. They did grow 13 acres of corn and 26 acres of hay, or a little larger acreage than required to furnish feed for the stock. Thus, with 39 acres used in growing corn and hay and 3 acres in fruit, etc., they had left from their total crop area of 57 acres 15 acres that were used in growing small grains.

Fewer silos have been built on the farms with 30 acres of crops or under than on the larger farms. Only three of these farms have silos, and two of these were not filled in 1916. The farms with so small a crop acreage seldom raise enough corn to fill a silo and have enough grain feed for a minimum number of stock. They more often do not raise enough to fill a silo. Of the farms with 30 acres and under of crops, one in six had silos in November, 1916; of those with 31 to 45 acres of crops, one in four had silos; and of those with over 45 acres of crops almost one-half had silos.

Most of the sheep were found in the larger farms, the flocks being larger on the large farms than on the small farms, and a greater

percentage of the farms keeping sheep. The receipts from the sale of sheep and wool were \$183 per farm, or one-sixth of the total receipts on the large farms, while they were \$50 per farm, or one-tenth of the total receipts on the small farms.

On the small farms the percentage of the total receipts from crops was much smaller than on the larger farms, the result of a smaller percentage of the crop area being in wheat. On the other hand, a larger percentage of the farm receipts were obtained from poultry on the small farms.

The small farms used a somewhat higher percentage of the farm receipts for expenses in operating the farm business than did the larger farms. The proportion of the total expenses for hired labor was a little less on the smaller farms, but that for depreciation and repairs and for feed was somewhat more. The other items of expense represented about the same percentage of the total expenses for all groups.

On the small farms the investment in land was proportionately less and that in dwellings more, and at the same time the dwellings were not so good as those on the large farms. The real estate was valued \$2 per acre more on the small farms.

The farms producing 45 acres or over of crops had a machinery investment of \$6.11 per crop acre, while those producing 30 acres or under of crops had an investment of \$7.67 per crop acre.

QUALITY OF BUSINESS.

As already shown (p. 48) the group of farms with the smallest business (smallest crop acreages) had the lowest average labor income, and the group with the largest business (largest crop acreages) had the highest average labor income. This is usually true of groups of farms, but it is not always true of individual farms; that is, not every farm having a large business has a higher income than every farm having a small business. In each size group of farms were farms with good labor incomes, and farms with poor labor incomes. These variations in labor income must have been partly due to some other cause or causes than the size of the business, and the most important other cause is the quality of business.

The quality of the farm business either for an individual farm or for groups of farms may be fairly well determined by comparing the crop yields per acre and the receipts per animal unit from live stock with the corresponding yields or receipts for all the farms studied.

Of course, the character and fertility of the soil and the climatic conditions have great influence in determining crop yields, but within a restricted area, such as that in Palmer Township, these influences

are very likely to affect one group of farms as much as another in a given year, so that it may be said safely that the variations in crop yields on different farms or groups of farms in an area with similar soil and climatic conditions are due more to variations in the farm practice on the different farms than to the conditions just named, and that the crop yields on the different farms are therefore one indication of the quality of the business conducted on them.

Receipts per animal unit are considerably affected by the prices received for the live stock and its products, by the time of selling, or by live-stock losses, but within a given area differences in receipts are often the results of actual differences in the quality of the stock or of differences in the live-stock practices on different farms. These practices, however, have been worked out or applied by the farmers after such study of the marketing problem and the problems of feeding and the care of stock as to enable them to reduce live-stock losses to a minimum and to have the right kind of stock to sell at the right time. The receipts per animal unit may therefore safely be said to be a very good indication of the quality of the live-stock part of the farm business.

The crop yields per acre and receipts per animal unit have been worked out by comparing the crop yields and receipts per animal unit on each farm for each year with the average yields and receipts for all farms for that year. This was done because the average yields of crops and receipts per animal unit were not uniform from year to year, owing generally to causes not entirely under the control of the farmers, such as weather conditions, insect injuries, or live-stock prices. Thus in this study of the effect of quality of the farm business upon profits, each farm was used as many times as there were yearly records for that farm, or a total of 245 records.

In Table XVI are shown the effects of the size and the quality of the farm business upon the labor income. In determining the effect of either of those factors, care must be exercised to make sure that the profits shown are not the resultant of a combination of the two factors, rather than of the one it is desired to study. To eliminate this source of error as far as possible, when determining the effect of quality upon farm profits, the records were grouped into three size groups (by crop area), and each of these into three groups based upon the quality of the business. From these groupings, the effect of the quality of the business upon the average labor income of groups of from 20 to 36 farm records with similar crop acreages may be noted by reading the table from left to right. The effect of the size of the business when the quality is similar may be noted by reading the table downward.

It will be seen that both size and quality have decided effects upon the labor income, and that quality is fully as important as size. The

small farms with poor quality had nothing left for the operator's labor after 5 per cent interest on the investment was deducted from the farm income. In other words, the average labor income for this group of farms was nothing. The average labor income of the large farm with poor quality was \$88, while that of the small farms with good quality was \$137. The medium-sized farms with medium quality had an average labor income of \$125. The labor income of the large farms with medium quality was \$213, while that of the medium-sized farms with good quality was \$214. These figures indicate that so long as the size of the business is small and the quality poor the income may be increased more by improving the quality of the business than by increasing the size, but that with a medium-sized business with medium quality, the income may be increased as much by increasing the size, while maintaining the same quality, as by improving the quality while maintaining the same size.

TABLE XV.—*Effects of size (crop area) and quality of business upon labor income (245 farm records, Palmer Township, Washington County, Ohio).*

[Figures represent average labor income.]

Size (crop area).	Poor quality. ^a	Medium quality. ^b	Good quality. ^c
30 acres and less.....		\$72	\$137
31 to 45 acres.....	\$63	125	214
Over 45 acres.....	88	213	453

^a Poor quality includes: Poor crops and poor stock; poor crops and medium stock; medium crops and poor stock.

^b Medium quality includes: Poor crops and good stock; medium crops and medium stock; good crops and poor stock.

^c Good quality includes: Medium crops and good stock; good crops and medium stock; good crops and good stock.

The influence of quality of the business, as shown in Table XV, is due to the combined weight of two quality factors, crop yields and receipts per animal unit. In order to determine the influence of each upon farm profits, the records were grouped so that farms with different crop yields but with similar live-stock receipts could be compared, and vice versa. These groupings show that for both crops and live stock quality had marked effects upon the average labor income, but that quality of live stock affected the income more than that of crops. The quality of the live stock had just about double the effect of the quality of the crops, and this should be expected in this area. It was pointed out on page 49 that much the greater proportion of the crops produced on these farms reached their market through the medium of the live stock rather than by selling the crop direct, and Table III shows that a much greater proportion of the farm receipts were from the live stock than from the crops. Therefore, with the type of farming followed in this area, the quality factor of first importance is the live stock. With

whatever quality of crops a farmer produces, so long as most of them are marketed through his live stock, it is more important to get good returns per animal per unit than to get higher crop yields per acre. This is not intended to minimize the importance of obtaining good crop yields, but to emphasize the importance of having a good quality of live stock.

The group of farms that had both poor crops and poor stock had an average labor income of \$4 per year. The group with no better stock but with good crops had an average labor income of \$134, while the group with no better crops but with good stock had an average labor income of \$216.

The group of farms with medium crop yields and medium stock had an average labor income of \$108. The group with no better stock but with good crop yields had an average labor income of \$212, while the group with no better crops but with good stock had an average labor income of \$302.

The farms with both good crops and good stock had the highest average labor income—\$397.

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PROFESSIONAL PAPER

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DIGESTIBILITY OF PROTEIN SUPPLIED BY SOY-BEAN AND PEANUT PRESS-CAKE FLOURS.¹

By ARTHUR D. HOLMES, *Specialist in Charge of Digestion Experiments, Office of Home Economics.*

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INTRODUCTION.

It has long been recognized that in order to maintain the well-being of an individual, or in fact to maintain the normal body processes, proteins of sufficient quantity and quality are absolutely essential. The proteins normally occurring in the human dietary are of a quite varied nature and are derived from both the animal and vegetable kingdoms. Those foods which contain the largest proportion of protein and are ordinarily referred to as protein-rich foods are obtained largely from the animal kingdom and include such food materials as meats, eggs, and milk.

¹ Prepared under the direction of C. F. Langworthy, Chief, Office of Home Economics.

NOTE.—This bulletin records studies of the digestibility of protein supplied by soy-bean and peanut press-cake flours. It is primarily of interest to students and investigators of food problems.

The many studies which have been made to determine the actual importance for dietary purposes of the proteins supplied by meats, eggs, and milk show quite conclusively that these proteins are of high biologic value. Unfortunately the supply of these food materials is becoming constantly less adequate to meet the needs of the very rapidly increasing population of this country. Furthermore, these foods are relatively expensive, and consequently can not be eaten as freely as formerly by those of small incomes. As a result of these conditions, students of nutrition have given considerable attention to the possibility of replacing animal proteins with vegetable proteins, and as a consequence the demand for vegetable foods which supply proteins that are of value for human food is steadily increasing. The cereals which contain relatively small amounts of protein are already so extensively used that as a group they now supply nearly one-half of the total protein of the average American diet. While practically all of the common vegetable foods contain protein, the amount present in foods of vegetable origin is small except in the case of the legumes, which may be classed as protein-rich food. Accordingly it appears that a more extensive use of legumes as a source of protein is to be desired. Those legumes most commonly used in this country are the well-known navy beans, red kidney, and lima beans, the garden pea, frijoles, pinto beans, and several varieties of cowpeas. Many studies have been made of the nutritive value and possible uses of these legumes, and several investigators have conducted experiments to determine their digestibility.

INVESTIGATIONS OF DIGESTIBILITY OF COMMON LEGUMES.

The digestibility of hulled peas cooked thoroughly until soft and passed through a sieve was determined by Rubner,¹ who found that the protein was 72 per cent digested. In a second experiment in which the subject ate 600 grams of peas per day the digestibility was found to be 83 per cent.

Malfatti² determined the digestibility of the protein supplied by a porridge made of split peas and found it to be 86 per cent digested.

Richter³ reported that in an experiment in which the subject consumed 600 grams of purée of pea the protein was 90 per cent digested.

Snyder⁴ conducted three experiments to determine the digestibility of pea protein and served a porridge (containing 82 per cent of water) made from dried peas. The porridge was eaten in conjunction with a basal ration consisting of rice, milk, and sugar; one-third of the protein of the diet was supplied by the peas. He found that the average digestibility of the pea protein was 80 per cent.

¹ Ztschr. Biol., 16 (1880), No. 1, pp. 119-128.

² Jahresber. Tier-Chem., 15 (1885), p. 412.

³ Arch. Hyg., 46 (1903), No. 3, pp. 264-273.

⁴ Minnesota Sta. Bul. 92 (1905), pp. 267-270.

Prausnitz¹ in a study of the digestibility of white beans cooked in salted water until soft found that the protein was approximately 70 per cent digested.

Snyder² studied the digestibility of navy beans which were prepared by cooking for 20 minutes in boiling water containing bicarbonate of soda, removing the skins, and baking the hulled beans in the usual way. The results of three experiments indicated that bean protein was 80 per cent utilized.

Woods and Mansfield,³ in a study of the digestibility of rations for lumbermen, included three experiments in which the ration contained beans, and found that the digestibility of the protein of the total diet was 85 per cent, and estimated that the digestibility of the bean protein was 78 per cent.

Wait⁴ conducted a series of 72 experiments to determine the digestibility of kidney beans, white beans, and three varieties of cowpeas eaten in conjunction with a basal ration consisting of bread, milk, butter, pork, bananas, and sugar, and found that the coefficients of digestibility of the proteins were as follows: Kidney beans 77 per cent, white beans 78 per cent, Whippoorwill cowpeas 70 per cent, Clay cowpeas 74 per cent, and Lady cowpeas 83 per cent.

The general conclusion to be drawn from the experimental data cited above is that while the proteins of the more widely used legumes are quite well utilized by the human body, comparing very favorably in this respect with the cereal proteins, they are not as completely utilized as the proteins supplied by such animal foods as meats, eggs, and milk.

SOURCE AND AVAILABLE SUPPLY OF SOY-BEAN AND PEANUT PRESS CAKE.

Considerable interest has recently been aroused regarding the nutritive value of two legumes, soy beans, which as yet have not been extensively used in this country for food purposes, and peanuts, which, though well known and commonly eaten, have been used as a casual rather than a staple article of diet. It is of course true that soy beans have found limited use in some localities and that peanuts have been quite extensively used as a constituent of confectionery, as "salted peanuts," and more recently as "peanut butter," but neither has been very extensively used in the manner in which peas and beans appear in the dietary.

During very recent years the production of both these legumes has grown many fold. The increase in the culture of peanuts is due very likely to the fact that the boll weevil has made the growing of

¹ Ztschr. Biol., 26 (1890), pp. 227-232.

² Minnesota Sta. Bul. 74 (1902), p. 122.

³ U. S. Dept. Agr., Office Expt. Stas. Bul. 149 (1904), pp. 60, pls. 4.

⁴ U. S. Dept. Agr., Office Expt. Stas. Bul. 187 (1907), pp. 55.

cotton unprofitable in many sections of the South and peanuts are now grown as a supplementary crop. The recent increase in the production of soy beans has probably resulted primarily from the present great need of additional food materials for both human and animal consumption.

The present imperative demand for oils in the manufacture of explosives, coupled with the increased demand for oils for industrial and edible purposes, makes it highly probable that large quantities of soy beans and peanuts will be pressed in cottonseed-oil mills where the machinery is adapted for the expression of oil from these oil-bearing seeds as well as cotton seed.

It has been estimated¹ that 150,000 bushels, or 9,000,000 pounds of soy beans was pressed during the season (1917-18) in North Carolina alone, which produced more than 3,500 tons of press cake. In addition to the supply of domestic soy beans there are large quantities of beans which have been imported from other countries. It is also reported² that the greater portion of the present unusually large crop of peanuts will be pressed. The residue, which remains after most of the oil has been removed from soy beans and peanuts, commercially known as press cake, contains a high percentage of protein. Such press cake has been very largely used as stock feed and, because of its high nitrogen content, for fertilizing purposes. It is at once apparent, however, that if care were exercised in grading and cleaning sound soy beans and in shelling and sorting sound peanuts, and if they were pressed under sanitary conditions, the resulting press cakes should be of considerable value for use as human food, and especially as a source of protein. Furthermore, since the oil is not fully extracted by pressing, the "cakes" are also an important source of fat. Thus it would seem that the extensive studies which have already been made of the soy-bean and peanut proteins are of a very definite value and that further studies of the possible uses and value of high-grade soy-bean and peanut press cakes for human food are to be desired.

FACTORS CONSIDERED IN DETERMINING FOOD VALUE OF A PROTEIN.

In considering the value of any material as a source of protein for food purposes, at least three factors are ordinarily considered, namely, the amount, the quality, and the digestibility of the protein supplied by the material in question. The amount of the protein present in the material under consideration is determined by chemical analysis. The quality of the protein ordinarily is determined by either, or preferably both, of two methods: By ascertaining the number and nature of the amino acids making up the protein molecule,

¹ Personal communication, Forage Crop Investigations, Bureau Plant Industry.

² Personal communication, Bureau of Chemistry.

or by ascertaining the biologic value of the protein by means of carefully controlled feeding experiments with laboratory animals. Such experiments give data regarding the ability of a protein to support normal life processes, such as growth, maintenance, and reproduction. The amount of protein retained for body uses from the food eaten is generally determined by digestion experiments in which the protein under consideration appears as the sole or major portion of the protein in the diet.

The amount of protein supplied by soy-bean and peanut press-cake flours would obviously vary somewhat with the varieties of the legumes from which the flours were made and with the process of manufacture. Proximate analysis of the dried soy beans and peanuts shows them to have the following composition: Soy beans,¹ water 9.9 per cent, protein 36.5 per cent, fat 17.5 per cent, carbohydrates 30.8 per cent, and ash 5.3 per cent, the fuel value being approximately 1,950 calories per pound; peanuts², water 9.2 per cent, protein 25.8 per cent, fat 38.6 per cent, carbohydrates 24.4 per cent, and ash 2 per cent, the fuel value being approximately 2,480 calories per pound. When the oil is expressed from these legumes the percentage of protein is correspondingly increased and the resulting commercial press cakes ordinarily contain from 40 to 50 per cent of protein. The press cakes used in the study here reported, which were obtained by expressing oil from soy beans and peanuts in a small-sized expeller type of oil press, contained a larger amount of protein. But in any case the press cake should be classed as protein-rich material and on the basis of chemical analysis alone may well be considered as valuable food material. In order to ascertain the true value of these proteins for dietary purposes it is necessary to consider the factors referred to above, first, the quality of the protein as shown by the nature of the amino acids supplied and by its biologic value, and second, the digestibility of the protein.

THE AMINO ACIDS SUPPLIED BY SOY-BEAN AND PEANUT PROTEINS AS COMPARED WITH THOSE SUPPLIED BY COMMON CEREAL PROTEINS.

Since in the commercial utilization of soy-bean and peanut flours as human food these flours would, in all probability, be grouped with the cereal flours and meals, it is natural to compare the amino acids obtained from glycinin, the principal protein of soy beans, and arachin, the principal protein of peanuts, with gliadin, zein, rye-prolamin, oryzinin, and hordein, the principal proteins of wheat, corn, rye, rice, and barley, respectively.

¹ Personal communication, average of 121 analyses reported by Forage Crop Investigations, Bureau Plant Industry.

² U. S. Dept. Agr., Office Expt. Stas. Bul. 28 (1899), pp. 75.

A review of the literature of protein chemistry shows that while in general they are of a very complex structure the vegetable proteins yield on hydrolysis nearly all of the 16 amino acids which normally result from the decomposition of protein material. While all of these amino acids supply elements of value for food purposes, the results of carefully-controlled feeding experiments show conclusively that the dietary value of the different amino acids varies materially.

No résumé of the literature of protein and amino acid chemistry would be complete without special reference to the extensive investigations of Osborne¹ to whom the present interest in this subject is in no small measure due. In this brief discussion of amino acids it is impossible to more than refer to the investigations which have been carried out by Osborne et al.,² Henderson and Dean,³ Kauffmann,⁴ Cohnheim,⁵ Abderhalden and coworkers,⁶ Henriques,⁷ Willcock and Hopkins,⁸ Müller,⁹ Rona and Müller,¹⁰ Michaud,¹¹ McCollum et al.,¹² Folin and Denis,¹³ Hart and assistants,¹⁴ Kajiura,¹⁵ Wheeler,¹⁶ Underhill,¹⁷ Nollau and Kastle,¹⁸ Johns,¹⁹ and Geiling,²⁰ to determine

¹ Amer. Chem. Jour., 13 (1891), pp. 327-347, 385-414; 14 (1892), pp. 212-224, 629-661, 662-689. Amer. Chem. Jour., 19 (1897), pp. 236, 237. Jour. Amer. Chem. Soc., 16 (1894), pp. 633-643, 703-712, 757-764; 17 (1895), pp. 429-448, 539-567, 587-603. 19 (1897), pp. 525-532. Ztschr. Physiol. Chem., 33 (1901), pp. 225-239, 240-292. Amer. Jour. Physiol., 5 (1901), pp. 180, 181. Jour. Amer. Chem. Soc., 24 (1902), pp. 140-167. Proc. Soc. Expt. Biol. and Med., 5 (1908), pp. 105-107. Science, n. ser., 28 (1908), pp. 417-427. The Vegetable Proteins [London], Longmans, Green and Co., 1909. Ergeb. Physiol., 10 (1910), pp. 47-215.

² Jour. Amer. Chem. Soc., 16 (1894), pp. 778-785; 18 (1896), pp. 536-542, 542-558, 575-582, 583-609, 609-623; 19 (1897), pp. 454-482, 482-487, 487-494, 494-500, 509-513; 20 (1898), pp. 348-362, 362-375, 393-405, 406-410, 410-419, 419-428; 22 (1900), pp. 379-413; 25 (1903), pp. 323-353, 474-478, 837-842, 842-848, 848-853, 853-855. Amer. Jour. Physiol., 13 (1905), pp. 35-44, 436-447; 14 (1905), pp. 151-171, 259-286; 15 (1906), pp. 333-356; 17 (1906), pp. 231-265; 18 (1907), pp. 123-128, 295-308; 19 (1907), pp. 53-60, 117-124, 468-474, 475-481; 20 (1908), pp. 470-476, 477-493, 494-499; 22 (1908), pp. 362-372, 423-432; 23 (1908), pp. 180-200. Jour. Biol. Chem., 3 (1907), pp. 213-217, 219-225; 5 (1908), pp. 187-195, 197-205. Amer. Chem. Jour., 15 (1893), pp. 392-471. Jour. Biol. Chem., 10 (1911), No. 10, pp. 303-325; 12 (1912), No. 3, pp. 473-510, figs. 26; 13 (1912), No. 2, pp. 233-276, figs. 21; 14 (1913), No. 5, pp. 481-487; 17 (1914), No. 3, pp. 325-349, figs. 8; 18 (1914), No. 1, pp. 1-16, figs. 6; 20 (1915), No. 3, pp. 351-378, fig. 10; 22 (1915), No. 2, pp. 241-258, fig. 1; pp. 259-280; 25 (1916), No. 1, pp. 1-12, figs. 4; 29 (1917), No. 1, pp. 69-92, fig. 1.

³ Amer. Jour. Physiol., 9 (1903), No. 6, pp. 386-390.

⁴ Arch. Physiol. [Pflüger], 109 (1905), No. 9-10, pp. 440-465.

⁵ Hoppe-Seyler's Ztschr. Physiol. Chem., 49 (1906), No. 1, pp. 64-71.

⁶ Hoppe-Seyler's Ztschr. Physiol. Chem., 47 (1906), No. 4-6, pp. 354-358; 51 (1907), p. 232; 77 (1912), No. 1, pp. 22-58; 81 (1912), No. 4, pp. 323-328. Synthese der Zellbausteine in Pflanze und Tier. [Berlin, Julius Springer], 1912, p. 128.

⁷ Hoppe-Seyler's Ztschr. Physiol. Chem., 49 (1906), No. 2-3, pp. 113-123; 60 (1909), No. 2, pp. 105-118.

⁸ Jour. Physiol., 35 (1906), No. 1-2, pp. 88-102.

⁹ Arch. Physiol. [Pflüger], 112 (1906), No. 5-6, pp. 245-291, pls. 2, fig. 1.

¹⁰ Hoppe-Seyler's Ztschr. Physiol. Chem., 50 (1907), No. 4-5, pp. 263-280.

¹¹ Ztschr. Physiol. Chem., 59 (1909), No. 5-6, pp. 405-491.

¹² Amer. Jour. Physiol., 29 (1911), No. 2, pp. 215-237. Jour. Biol. Chem., 19 (1914), No. 3, pp. 323-333; 2. (1915), No. 1, pp. 181-230, figs. 42; 20 (1915), No. 3, pp. 415-428, figs. 12; 28 (1916), No. 1, pp. 153-165, figs. 10, No. 1, pp. 211-229, figs. 17; No. 2, pp. 483-500, pl. 1, figs. 12.

¹³ Jour. Biol. Chem., 11 (1912), No. 1, pp. 87-95.

¹⁴ Jour. Biol. Chem., 13 (1912), No. 2, pp. 133-153, figs. 4; 19 (1914), No. 3, pp. 373-395, pl. 1, figs. 11. Wisconsin Sta. Research Bul. 17 (1911), pp. 205, pls. 19. Jour. Biol. Chem., 25 (1916), No. 2, pp. 239-260, pls. 9, figs. 9; 29 (1917), No. 1, pp. 57-68, pl. 1.

¹⁵ Bio-Chem. Jour., 6 (1912), pp. 171-181.

¹⁶ Jour. Expt. Zool., 15 (1913), pp. 209-223.

¹⁷ The Physiology of the Amino Acids, F. P. Underhill, New Haven: Yale Univ. Press, 1915, pp. 169, pl. 1, figs. 13.

¹⁸ Amer. Jour. Physiol., 39 (1915-16), No. 2, pp. 162-171, pls. 8. Kentucky Sta. Bul. 197 (1916), pp. 21, pls. 16.

¹⁹ Jour. Biol. Chem., 28 (1916), No. 1, pp. 59-65, 67-75, 77-87.

²⁰ Jour. Biol. Chem., 31 (1917), No. 1, pp. 173-199.

the nature and nutritive value of proteins, especial attention being given to the amino acids supplied. While it was found that under some conditions tyrosine, cystine, arginine, histidine, glutamic and aspartic acids may act as limiting factors in the diet, it seems to be very generally recognized by these students of nutrition that the two amino acids, lysine and tryptophane, are of especial importance in the dietary, lysine being essential for "growth" and tryptophane essential for "maintenance." In view of these conclusions it appears desirable to compare the amino acids resulting from the hydrolysis of soy-bean and peanut proteins with those obtained by the hydrolysis of the common cereal proteins. The amounts of amino acids resulting from the hydrolysis of the principal proteins of some common cereals are brought together in the following table for comparison with those obtained by hydrolyzing glycinin and arachin:

Amino acids resulting from hydrolysis of proteins of cereals.

Amino acids.	Gliadin, wheat.	Zein, ³ corn.	Rye, ⁴ prolamin.	Oryzinin, rice.	Hordein, ⁷ barley.	Glycinin, ⁸ soy bean.	Arachin, ⁹ peanut.
Glycine.....	¹ 0.00	0.00	0.13	⁵ (?)	0.00	0.97	0.00
Alanine.....	¹ 2.00	9.79	1.33	⁵ 3.7	.43	Not isolated.	4.11
Valine.....	¹ 3.34	1.88	Not isolated.	⁵ (?)	.13	.68	1.13
Leucine.....	¹ 6.62	19.55	6.30	⁵ 14.3	5.67	8.45	3.88
Proline.....	¹ 13.22	9.04	9.82	⁵ 3.3	13.73	3.78	1.37
Phenylalanine.....	¹ 2.35	6.55	2.70	⁵ 2.0	5.03	3.86	2.60
Aspartic acid.....	¹ .58	1.71	.25	⁵ .4	Not isolated.	3.89	5.25
Glutamic acid.....	¹ 43.66	26.17	38.05	⁵ 14.5	43.20	19.46	16.69
Serine.....	¹ .13	1.02	.06	(⁶)	Not isolated.	Not isolated.	Not isolated.
Tyrosine.....	¹ 1.20	3.55	1.19	⁵ .5	1.67	1.86	5.50
Cystine.....	¹ .45		Not estimated.	⁵ 1.26	Not estimated.	-----	.85
Arginine.....	¹ 3.16	1.55	2.22	⁵ 9.15	2.16	5.12	13.51
Histidine.....	² 2.19	.82	.39	⁵ 3.32	1.28	1.39	1.88
Lysine.....	² 1.21	.00	.00	⁵ 4.26	.00	2.71	4.98
Ammonia.....	¹ 5.22	3.64	5.11	⁵ 3.23	4.87	2.56	2.03
Tryptophane.....	¹ 1.00		Present.	(⁶)	Present.	Present.	Present.

¹ Jour. Biol. Chem., 9 (1911), No. 5, p. 426.

² Jour. Biol. Chem., 22 (1915), No. 2, p. 261.

³ Amer. Jour. Physiol., 26 (1910), No. 4, p. 304.

⁴ Osborne, Ergeb. Physiol., 10 (1910), p. 86. (In the absence of a name for rye protein, Osborne referred to the alcohol soluble protein as rye prolamin.)

⁵ Osborne, Ergeb. Physiol., 10 (1910), p. 112.

⁶ Jour. Biol. Chem., 22 (1915), No. 2, p. 275.

⁷ Osborne, Ergeb. Physiol., 10 (1910), p. 90

⁸ Osborne, Ergeb. Physiol., 10 (1910), p. 132.

⁹ C. O. Johns and D. B. Jones. To be published in the Journal of Biological Chemistry.

It will be noted on referring to the above table that the earlier analyses of gliadin, zein, rye-prolamin, oryzinin, and hordein indicated that these proteins supplied little if any lysine and tryptophane. In the more recent studies of oryzinin and gliadin it was found that on hydrolysis these proteins yield appreciable amounts of lysine. An unpublished investigation by C. O. Johns and A. J. Finks, Bureau of Chemistry, shows that hordein on hydrolysis yields approximately the

same amount of lysine as gliadin. However, the amount of these cereal proteins in some of the cereals is insufficient to supply adequate amounts of the essential amino acids, whereas soy beans and peanuts are rich in glycinin and arachin which yield a high percentage of lysine. In considering the dietary value of glycinin and arachin, from the standpoint of lysine and tryptophane, the consensus of opinion of biochemists seems to be well summed up in the conclusions of Osborne and Mendel¹ who state "We have shown that growth does not occur when lysine is lacking from the diet but takes place promptly on adding this amino acid to the otherwise adequate food," and in the conclusions expressed by Abderhalden,² who says that tryptophane is an indispensable component in the dietary.

It may also be noted, in discussing the relative nutritive value of proteins as regards the presence or absence of lysine and tryptophane, that Osborne and Mendel³ state that lysine must be present in the diet since "the animal organism apparently can not synthesize lysine." These authors⁴ also state that "Tryptophane can not be synthesized by the animal cells." Accordingly, a theoretical consideration of the relative nutritive value of soy-bean and peanut proteins, based upon their amino-acid content alone would indicate that glycinin and arachin possessed a greater dietary value than the principal proteins supplied by the common cereals.

BIOLOGIC VALUE OF SOY-BEAN AND PEANUT PROTEINS AS COMPARED WITH THAT OF COMMON CEREAL PROTEINS.

Feeding experiments have been made by a number of investigators for the purpose of securing data regarding the relative biological value of proteins supplied by some of the cereals referred to above. Willcock and Hopkins⁵ state that "loss of weight begins the moment it [zein] forms the sole nitrogenous supply." Osborne and Mendel⁶ report "We have now accumulated the results of a large experience in feeding zein, with the uniform consequence of decline when this protein forms the sole nitrogenous component of the dietary." These results have been confirmed by Wheeler⁷ in studies with rats and later by Hart and McCollum,⁸ who report that young pigs can not grow when the maize kernel is the sole source of nutriment. Hogan⁹ conducted experiments to determine the value of corn protein, zein, when fed as the sole source of protein, and concluded that trypto-

¹ Jour. Biol. Chem., 25 (1916), No. 1, p. 2, figs. 4.

² Hoppe-Seyler's Ztschr. Physiol. Chem., 96 (1915), No. 1-2, pp. 1-147.

³ Jour. Biol. Chem., 17 (1914), No. 3, p. 334.

⁴ Ibid., p. 328.

⁵ Jour. Physiol., 35 (1906), No. 1-2, p. 100.

⁶ Jour. Biol. Chem., 17 (1914), No. 3, p. 338.

⁷ Jour. Expt. Zool., 15 (1913), No. 2, pp. 209-223.

⁸ Jour. Biol. Chem., 19 (1914), No. 3, pp. 373-395, pls. 2, figs. 11.

⁹ Jour. Biol. Chem., 29 (1917), No. 3, pp. 485-493, figs. 3.

phane was the first limiting factor and lysine the second when all other factors known to be essential to the dietary have been supplied.

The nutritive value of the principal protein of wheat, gliadin, has also been carefully studied. Osborne and Mendel¹ found that "in order to promote the growth of experimental animals it is necessary to supplement gliadin with lysine."

Hart and McCollum² report "It is evident that the whole-wheat grain will not sustain growth and even leads to physiological disturbances when continued as the sole source of nutrients for but a short span of the entire period of growth." In a later paper Hart, McCollum, Steenbock, and Humphrey³ conclude that an exclusive diet of wheat grain and wheat straw is wholly inadequate with heifers for reproduction and in some instances for continued growth.

The proteins of rye, rice, and barley have received much less attention by investigators than those of wheat and corn. It appears that while rice and barley supply small amounts of total protein, orzinin and hordein supply relatively large amounts of lysine. Osborne, Van Slyke, Leavenworth, and Vinograd⁴ in comparing the basic substances yielded by the proteins of the endosperm of wheat (lysine 1.58), maize (lysine 0.97), and rice (lysine 4.26) with the figures reported by Thomas⁵ for the percentage of assimilable nitrogen 40 per cent, 29 per cent, and 88 per cent, respectively, say "It is rather striking that the figures for the utilizability of these proteins correspond so closely with the lysine which they yield."

Buckner, Nollau, and Kastle⁶ in experiments with chickens included a diet in which both barley and rice were fed in conjunction with hominy, oats, and gluten, and were of the opinion that the unsatisfactory growth which resulted could be attributed to the low lysine content of the diet, which probably means that only small quantities of rice were eaten. Osborne and Mendel report feeding experiments with rats in which concentrated oat, rice, and barley proteins were added to an otherwise adequate diet. They state⁷ that "the total proteins of rice and barley in contrast with maize and oats, when furnished in diets containing 16 to 17 per cent of protein, supply enough of all the amino acids essential for growth."

It is interesting to compare these conclusions regarding the value of the cereal proteins with the conclusions reported regarding the value of soy-bean and peanut proteins. In a study of the relative value of some common proteins as supplements to corn gluten Os-

¹ Jour. Biol. Chem., 17 (1914), No. 3, pp. 325-349, figs. 8.

² Jour. Biol. Chem., 19 (1914), No. 3, p. 276.

³ Loc. cit.

⁴ Jour. Biol. Chem., 22 (1915), No. 2, p. 276.

⁵ Arch. Anat. u. Physiol., Physiol. Abt., 1909, pp. 257, 259, 261.

⁶ Amer. Jour. Physiol., 39 (1916), No. 2, pp. 162-171.

⁷ Jour. Biol. Chem., 34 (1918), No. 3, p. 531.

borne and Mendel¹ included experiments with a commercial soy-bean flour and a peanut meal (prepared by grinding peanuts from which the oil had been extracted) in a series containing such materials as casein, lactalbumin, edestin, cottonseed protein, fish-meat meal, corn-oil cake, "vegetable-albumin flour" (largely gliadin), brewers' grains (largely residues of corn and barley proteins), and pea meal. The authors state, "An inspection of these tables shows that lactalbumin is the most efficient supplement—those which are equally efficient are milk albumin and soy-bean flour." The gain in weight reported for the experimental animals which were fed a diet which included the peanut meal indicated that this material ranks high as a supplement to corn gluten. As a result of these facts the authors conclude that "The efficiency of these supplements presumably depends essentially upon their relative content of lysine and tryptophane."

Osborne and Mendel report² in a study of the relative values for functions of growth of isolated proteins included in a diet consisting of an isolated protein, protein-free milk, starch, agar, and fat that they were able to secure active growth with casein, ovalbumin, lactalbumin, edestin, glutenin, and glycinin (soy-bean protein), and that they secured little or no growth with gliadin, hordein, and zein.

Osborne and Mendel³ in a report of results of experiments made with rats say "On diets containing either the soy-bean meal or the commercial soy-cake meal, together with fats and "Protein-free milk" or our "artificial" salt mixture, several broods of vigorous young have been produced, and these young have grown normally on diets the same as those on which their parents were raised. This is a further demonstration of the nutritive efficiency of this legume, in striking contrast with the adverse results obtained with kidney beans and garden peas."

Daniels and Nichols⁴ as the result of experiments with rats conducted to determine the biologic value of protein supplied by soy beans which had been cooked 30–40 minutes under 15 pounds pressure concluded that—

The value of the protein of the soy bean has been demonstrated in all of our experiments. That animals fed rations containing 15.6 and 18.7 per cent of protein obtained solely from the soy bean have grown normally and in the latter case * * * [with the larger percentage of soy-bean protein] have produced successive litters of young, which in turn have reproduced, is sufficient evidence that the protein of the soy bean fulfills all physiologic requirements. The protein of the soy bean appears to be quite as valuable as the casein of milk. These findings are somewhat surprising in view of the fact that the protein of other legumens, namely peas and white beans, has been found wanting.

¹ Jour. Biol. Chem., 29 (1917), No. 1, p. 77.

² Carnegie Inst. Washington Pub. No. 156, pt. 2, p. 83.

³ Jour. Biol. Chem., 32 (1917), No. 3, p. 375.

⁴ Jour. Biol. Chem., 32 (1917), No. 1, p. 95.

While several investigators are giving attention to the nature and value of the peanut proteins, as yet little information has been reported regarding the biologic value of these proteins. Daniels and Loughlin ¹ have recently reported a study of two peanut meals; one of which was ground roasted peanuts which contained the normal amount of peanut oil, the second was ground press cake which contained a relatively small amount of peanut oil. Regarding the biologic value of peanut proteins the authors state—

Rations consisting of 67.5 grams of peanut meal, supplying 18 per cent protein, 10 grams of lard, 5 grams of butter fat, 11.4 grams of cornstarch, and 5.09 grams of suitable inorganic material proved satisfactory in every way. The curves of growth * * * [as one of the charts accompanying the paper shows] in all cases were similar to those generally considered to be normal. Reproduction occurred at frequent intervals and three generations were obtained. Good growth was secured also with a ration supplying 15 per cent protein from the peanut meal. The proteins of peanuts are comparable to those of the soy bean, since it has been shown that both legumes supply the essential amino acids in sufficient amounts for normal growth and reproduction.

In discussing the value of soy-bean flour it should also be noted that this material is especially valuable for food purposes since it supplies the water-soluble and to a limited extent the fat-soluble accessories essential in a complete diet. In this connection Daniels and Nichols ² say:

It contains a high percentage of a physiologically good protein, a considerable amount of energy-yielding material in the form of fat and carbohydrate, and a fairly liberal supply of the fat-soluble food accessory, as well as of the water-soluble growth determinant.

And Osborne and Mendel ³ state that—

So far as we are aware the soy bean is the only seed hitherto investigated, with the possible exception of flax and millet, which contains both the water-soluble and [in limited quantity] the fat-soluble unidentified dietary essentials or vitamins. This fact, taken with the high physiological value of the protein, lends a unique significance to the use of the soy bean as food.

Referring to the presence of the fat-soluble and water-soluble food accessories in peanut meal Daniels and Loughlin ⁴ say:

That peanuts are lacking in the fat-soluble food accessory has been shown by the behavior of animals which were given rations containing no butter fat * * * . Since all the animals receiving the 5 per cent butter-fat ration were normal in every respect, proof is furnished for the presence of a considerable amount of the water-soluble food accessory in the diets. When the peanuts formed 56 per cent of the ration, there was sufficient water-soluble B for the experimental animals. Like the soy bean, it needs only to have added suitable inorganic material and some of the fat-soluble food accessory to make it a complete food.

¹ Jour. Biol. Chem., 32 (1918), No. 2, p. 296.

² Jour. Biol. Chem., 32 (1917), No. 1, p. 96.

³ Jour. Biol. Chem., 32 (1917), No. 3, p. 376.

⁴ Loc. cit.

Osborne and Mendel¹ also report that they have been able to demonstrate the presence of the water-soluble food accessory in peanut meal.

In summarizing the studies of the nature and value of soy-bean and peanut proteins, referred to above, it appears first that chemical analysis of glycinin and arachin shows them to be relatively rich in lysine and tryptophane, amino acids essential for growth and maintenance, and second that studies of their biologic value show them to be more efficient proteins than those supplied by the common cereals or many of the common legumes. It appears then from these facts that soy-bean and peanut proteins have a high nutritive value and that further studies of their value in the human dietary are to be desired.

THE DIGESTIBILITY OF SOY-BEAN AND PEANUT PROTEINS.

This investigation was undertaken for the purpose of determining the digestibility of these proteins by normal individuals when eaten as a constituent of a simple mixed diet. It is of course recognized that the oil remaining in the soy-bean and peanut flours contributes to the food value of these flours, but no special attention is given to these oils in this study since previous studies of peanut² and soy-bean oils³ have shown that both are very well utilized by the human body.

PREPARATION OF SOY-BEAN AND PEANUT PRESS-CAKE FLOURS.⁴

The soy-bean flour used in the experiments which follow was prepared by expelling the oil from 2 bushels of well-cleaned Mammoth Yellow soy beans which had been grown under controlled experimental conditions by Forage Crop Investigations of the Bureau of Plant Industry. In order to secure a more nearly complete removal of the oil than is usual, the cake was pressed a second time. The press cake thus obtained was of a yellow color and retained about 8 per cent of oil. It was ground in a small-sized burr mill until all of the meal passed through a millimeter sieve. Through the courtesy of H. S. Bailey, of the Bureau of Chemistry, it was possible to prepare both the soy-bean and peanut flours under conditions approximating those of the commercial oil mill, using for this purpose a continuous process expeller type of oil-expressing machine.

In order to secure data relative to the fineness of this flour, a sample was bolted, and it was found that 53 per cent of the flour remained on the 40-mesh sieve, 23 per cent remained on the 70-mesh sieve, 9 per cent remained on the 90-mesh sieve, 3 per cent remained

¹ Jour. Biol. Chem., 32 (1917), No. 3, p. 310.

² U. S. Dept. Agr. Bul. 505 (1917), p. 18.

³ U. S. Dept. Agr. Bul., 687 (1918), p. 6.

⁴ In this paper the term "flour" is used without reference to the coarseness of the ground soy-bean and peanut press cakes.

on the 109-mesh sieve, and 12 per cent passed through the 109-mesh sieve. In view of the high protein content of the soy-bean press cake it seemed of interest to determine whether the distribution of nitrogen was uniform for the fractions remaining on the different-sized sieves. For this purpose a press cake which had been ground to duplicate the fineness of commercial soy-bean flour was chosen. That portion remaining on the 40-mesh sieve contained 5.95 per cent of nitrogen, that on the 70-mesh sieve 7.62 per cent, that on the 90-mesh sieve 8.06 per cent, that on the 109-mesh sieve 8.21 per cent, and the portion that passed through the 109-mesh sieve contained 8.32 per cent of nitrogen.

As often prepared in the commercial expression of peanut oil, the peanut press cake contains, in addition to peanut kernels, the shells and the thin red skin which surrounds the kernel. Consequently such commercial press cake, though suited for use as stock feed or fertilizer, is not suitable for food purposes; especially is this true when moldy or unsound peanuts are included, when the shells are dirty, or when the oil is not expressed under sanitary conditions. In the commercial preparation of "salted peanuts" clean shelled peanuts of good quality are "blanched" by subjecting them to an atmosphere of live steam just long enough to loosen the skin surrounding the kernels but not long enough to allow the kernels to absorb any appreciable amount of water vapor. A subsequent agitation of these kernels in a container provided with either a suction or a blower separates the skins from the kernels. The expression of oil by the cold process from such kernels produces a virgin oil and a high-grade press cake rich in protein. If shelled peanuts, from which the surrounding skin has not been removed, are pressed the resulting flour, though satisfactory for food purposes, is of a reddish tinge and has a somewhat different and less-pleasing flavor than that of the flour prepared from blanched kernels.

In the study here reported of the digestibility of the proteins supplied by peanut flour a series of experiments was made with each of these types of flours. The peanut flour used in the first series of experiments was prepared by expressing the oil from blanched, roasted peanuts and grinding the resulting press cake. The flour used in the second series of experiments was prepared by the cold expression of shelled raw peanuts from which the red skin had not been removed. The reddish flour obtained did not possess the rich nut-like odor of that obtained from roasted kernels. A sample of the flour from the unroasted peanuts was bolted and sieved to secure data regarding its fineness, and it was found that 54 per cent of the flour remained on the 40-mesh sieve, 23 per cent on the 70-mesh sieve, 13 per cent on the 90-mesh sieve, 5 per cent on the 109-mesh sieve, and 5 per cent passed through the latter sieve.

THE SUBJECTS OF THE DIGESTION EXPERIMENTS.

Seven subjects with previous experience in experiments which were made to determine the digestibility of some edible fats assisted in this investigation. In general they were students of dental or medical schools and were of normal health and appetite. Their ages ranged from 20 to 40 years and their activities were such that they would be classified as moderately-active persons. As is always the case, they were instructed to exercise care in saving all uneaten portions of the food, in separating and collecting the feces, and in submitting reports concerning their physical condition before, after, and during the experimental period. Inasmuch as all seemed in their usual good physical condition throughout the entire time of the experiments, no detailed discussion of these reports is given.

PREPARATION OF EXPERIMENTAL DIETS.

As in all studies of this character, it was desired that the nutrient under consideration, in this case the proteins supplied by soy-bean and peanut flours, should comprise as large a portion as possible of the total protein of the diet. It is essential that the foods studied be prepared in an acceptable form and accordingly preliminary tests were made of a number of methods of preparing these flours for eating. As a result of these tests it appeared that "tea biscuits" similar to those so commonly made with wheat flour were well adapted to this purpose. The recipe used follows:

RECIPE FOR BISCUITS.

16 cups flour mixture.
16 tablespoons lard.

12 teaspoons salt.
10 tablespoons baking powder.

6 cups water.

In the soy-bean experiments the flour mixture was prepared by mixing equal portions of wheat flour and soy-bean flour. In the experiments with the peanut flour made from roasted kernels, the proportion was two-thirds wheat flour and one-third peanut flour, and in the experiments with peanut flour made from the raw kernels from which the red skin was not removed, the proportion was one to one. The wheat flour used in all cases was a commercial brand of patent flour.

Biscuits made with flour and soy-bean flour or peanut flour one to one were satisfactory when only one-half or three-fourths inch in thickness; thicker biscuits being very often rather "heavy," no doubt because the amount of gluten in the flour mixture was rather small. It was found that if the biscuits were very thoroughly baked (though not scorched) they possessed a much better flavor than those not so well done.

In order that the major portion of the protein supplied by the experimental diet should be derived from the soy-bean and peanut flours, the accessory foods were chosen to supply only a minimum of protein, and included oranges, butter, and tea or coffee with sugar if desired. Since the subjects ate very generous amounts of the biscuits but had a very limited diet in other respects it was thought that they would use large quantities of butter. It was found, however, that though they could have all they wanted they ate on an average only about 56 grams daily.

DETAILS OF THE EXPERIMENTS.

In this study of the digestibility of the proteins supplied by soy-bean and peanut flours the methods which were employed were very similar to those followed in the study of the grain sorghums.¹ The usual 3-day or 9-meal experimental period was considered satisfactory for this study. No attempt was made to maintain a uniform body weight of the subjects or to maintain nitrogen equilibrium during the period. As is usual in such cases, sufficient food material was prepared at one time to supply all the subjects for the entire experimental period, representative samples of all the foods being retained for analysis. These samples and those of the air-dried feces of each subject resulting from the experimental diet were analyzed in the usual way. The differences between the amounts of protein, fat, and carbohydrates present in the foods and in the feces were taken to represent the amounts of these constituents digested. This method of procedure gives data regarding the digestibility of protein, fat, and carbohydrate supplied by the entire diet. Since in this study the coefficients of digestibility of the soy-bean and peanut proteins are of special interest they have been estimated by making allowance for the undigested protein material occurring in the diet. The method followed in estimating the digestibility of the proteins supplied by the soy beans and peanuts is indicated by the following equations:

[Weight of protein in accessory food materials] $\times$ [Percentage of undigested protein in each] = [Protein in feces from food other than bread].

[Total protein in feces] - [Protein in feces from food other than bread] = [Weight of undigested bread protein.]

[Weight of protein in bread] - [Weight of undigested bread protein] $\div$ [Weight of protein in bread] = [Estimated percentage of availability of bread protein.]

In determining the amount of undigested protein present in the accessory food materials in the experimental diet it was assumed that

¹ U. S. Dept. Agr. Bul. 470 (1916), pp. 30.

the protein¹ of wheat flour was 93.8 per cent digested, the protein² of orange 85 per cent, and the protein² of butter was 97 per cent digested.

It is, of course, recognized that the calculated values so obtained, for a special food, in this case soy-bean and peanut proteins, are probably somewhat low, since they include the errors due to considering all fecal nitrogen not resulting from the accessory foods as undigested soy-bean or peanut nitrogen, whereas fecal nitrogen, as has been pointed out by Woods and Merrill,³ Crowther and Woodman,⁴ and others, is derived in part at least from bile residues, epithelial waste, stomach residues, mucus, and saliva. It is not believed, however, that in this instance the error occasioned by the inability to correct for this factor is significant, especially in view of the unusually large quantities of soy-bean or peanut proteins consumed.

THE DIGESTIBILITY OF PROTEIN SUPPLIED BY SOY-BEAN PRESS-CAKE FLOUR.

In spite of the very extensive use of soy beans by the oriental peoples there appears to be little experimental data reported regarding the digestibility of the proteins supplied by this protein-rich legume. However, the long use of the soy bean as a staple article of the diet by the Japanese and Chinese offers sufficient evidence that soy-bean protein is well tolerated by the human body. Oshima in a summary of Japanese nutrition investigations, which includes much interesting information regarding the digestibility of preparations of legumes in common use in Japan, reports three experiments⁵ in which the subjects ate approximately 200 grams of tofu (soy-bean curd) daily in conjunction with cooked rice. The average digestibility of the total protein supplied by these diets, of which 83 per cent was soy-bean protein, was 95 per cent.

Few studies of the digestibility of soy-bean protein have been made in this country. Mendel and Fine report⁶ an experiment of six days' duration in which soy beans supplied 90.5 per cent of the total nitrogen intake, the basal ration consisting of tomatoes, apples, oranges, milk, sugar, and butter. The soy beans were boiled in water for one-half hour and the tomatoes thoroughly incorporated with the resulting mush which had been salted to taste. The total nitrogen supplied by the diet was 85.3 per cent digested. The subject reported that he was in excellent condition throughout the whole experiment. Defecation was regular and no physiological disturbances were experienced. The same authors conducted two series of

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), p. 32.

² Connecticut Storrs Sta. Rpt. 1899, p. 104.

³ U. S. Dept. Agr., Office Expt. Stas. Bul. 143 (1904), p. 57.

⁴ Jour. Agr. Sci., 8 (1917), pp. 429-477, Part IV.

⁵ U. S. Dept. Agr., Office Expt. Stas. Bul. 159 (1905), pp. 224.

⁶ Jour. Biol. Chem., 10 (1911), pp. 433-458.

digestion experiments with laboratory animals (dogs). In the first series (three tests) the animals received a mush prepared by heating soy beans, lard, agar, bone ash, and water on a water bath for 4 to 6 hours. In the second series (nine tests) the animals were "subjected to a thorough treatment with indigestible nonnitrogenous materials, to remove, as far as possible, the accumulated intestinal débris," and were fed a mixture of soy beans, sugar, and lard which was allowed to stand in water overnight. During the first series the animals ate an average of 86 grams of soy beans daily and an average of 58 grams in the second series. The digestibility of the total nitrogen of the diet was for the first series 80 per cent and for the second 84 per cent.

In the present study the seven experiments conducted to determine the digestibility of the protein supplied by soy-bean flour were divided into two series, one of four and one of three tests. The interval between first and second series comprised a rest period of two days on an ordinary mixed diet followed by an experimental period of three days during which the digestibility of a vegetable fat was studied and this by a second rest period of four days on an ordinary mixed diet. The experimental conditions and the subjects were identical for both series of experiments. Four subjects living under normal conditions assisted in the experiments which are reported in the following tables:

Data of digestion experiments with soy-bean flour in a simple mixed diet.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbo-hydrates.	Ash.
Experiment No. 669, subject A. F.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Biscuits containing soy-bean flour	1,396.0	456.1	254.8	129.1	497.8	58.2
Fruit	828.0	719.5	6.6	1.7	96.1	4.1
Butter	210.0	23.1	2.1	178.5	.....	6.3
Sugar	135.0	.....	.....	.....	135.0	.....
Total food consumed	2,569.0	1,198.7	263.5	309.3	728.9	68.6
Feces	84.0	.....	29.4	16.4	21.6	16.6
Amount utilized .....	.....	.....	234.1	292.9	707.3	52.0
Per cent utilized .....	.....	.....	88.8	94.7	97.0	75.8
Experiment No. 670, subject P. K.:						
Biscuits containing soy-bean flour	1,571.0	513.3	286.7	145.3	560.2	65.5
Fruit	410.0	356.3	3.3	.8	47.6	2.0
Butter	316.0	34.8	3.1	268.6	.....	9.5
Sugar	181.0	.....	.....	.....	181.0	.....
Total food consumed	2,478.0	904.4	293.1	414.7	788.8	77.0
Feces	142.0	.....	53.4	33.4	36.3	18.9
Amount utilized .....	.....	.....	239.7	381.3	752.5	58.1
Per cent utilized .....	.....	.....	81.8	91.9	95.4	75.5
Experiment No. 671, subject J. C. M.:						
Biscuits containing soy-bean flour	1,178.0	384.8	215.0	109.0	420.1	49.1
Fruit	446.0	387.6	3.6	.9	51.7	2.2
Butter	192.0	21.1	1.9	163.2	.....	5.8
Sugar	276.0	.....	.....	.....	276.0	.....
Total food consumed	2,092.0	793.5	220.5	273.1	747.8	57.1
Feces	94.0	.....	36.0	13.4	30.4	14.2
Amount utilized .....	.....	.....	184.5	259.7	717.4	42.9
Per cent utilized .....	.....	.....	83.7	95.1	95.9	75.1

Data of digestion experiments with soy-bean flour in a simple mixed diet—Continued.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 672, subject A. A. R.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Biscuits containing soy-bean flour.....	1,296.0	423.4	236.5	119.9	462.2	54.0
Fruit.....	893.0	776.0	7.1	1.8	103.6	4.5
Butter.....	43.0	4.7	.4	36.6	.....	1.3
Sugar.....	154.0	.....	.....	.....	154.0	.....
Total food consumed.....	2,386.0	1,204.1	244.0	158.3	719.8	59.8
Feces.....	77.0	.....	28.5	12.1	25.9	10.5
Amount utilized.....	.....	.....	215.5	146.2	693.9	49.3
Per cent utilized.....	.....	.....	88.3	92.4	96.4	82.4
Experiment No. 678, subject P. K.:						
Biscuits containing soy-bean flour.....	1,629.0	528.0	287.7	83.4	653.4	76.5
Fruit.....	413.0	358.9	3.3	.8	47.9	2.1
Butter.....	400.0	44.0	4.0	340.0	.....	12.0
Sugar.....	246.0	.....	.....	.....	246.0	.....
Total food consumed.....	2,688.0	930.9	295.0	424.2	947.3	90.6
Feces.....	76.0	.....	27.1	13.7	22.3	12.9
Amount utilized.....	.....	.....	267.9	410.5	925.0	77.7
Per cent utilized.....	.....	.....	90.8	96.8	97.6	85.8
Experiment No. 679, subject J. C. M.:						
Biscuits containing soy-bean flour.....	1,245.0	403.5	219.9	63.7	499.4	58.5
Fruit.....	466.0	405.0	3.7	.9	54.1	2.3
Butter.....	206.0	22.6	2.1	175.1	.....	6.2
Sugar.....	257.0	.....	.....	.....	257.0	.....
Total food consumed.....	2,174.0	831.1	225.7	239.7	810.5	67.0
Feces.....	85.0	.....	30.3	10.5	30.4	13.8
Amount utilized.....	.....	.....	195.4	229.2	780.1	53.2
Per cent utilized.....	.....	.....	86.6	95.6	96.2	79.4
Experiment No. 680, subject A. A. R.:						
Biscuits containing soy-bean flour.....	1,239.0	401.6	218.8	63.4	497.0	58.2
Fruit.....	1,384.0	1,202.7	11.1	2.8	160.5	6.9
Butter.....	46.0	5.1	.4	39.1	.....	1.4
Sugar.....	230.0	.....	.....	.....	230.0	.....
Total food consumed.....	2,899.0	1,609.4	230.3	105.3	887.5	66.5
Feces.....	95.0	.....	31.6	7.8	40.5	15.1
Amount utilized.....	.....	.....	198.7	97.5	847.0	51.4
Per cent utilized.....	.....	.....	86.3	92.6	95.4	77.3
Average food consumed per subject per day.....	823.1	355.8	84.4	91.6	268.1	23.2

Summary of digestion experiments with soy-bean flour in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of soy-bean protein alone.
		Protein.	Fat.	Carbo- hydrates.	Ash.	
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
669.....	A. F.	88.8	94.7	97.0	75.8	88.0
670.....	P. K.	81.8	91.9	95.4	75.5	79.4
671.....	J. C. M.	83.7	95.1	95.9	75.1	81.6
672.....	A. A. R.	88.3	92.4	96.4	82.4	87.5
678.....	P. K.	90.8	96.8	97.6	85.8	90.2
679.....	J. C. M.	86.6	95.6	96.2	79.4	85.2
680.....	A. A. R.	86.3	92.6	95.4	77.3	85.0
Average.....	.....	86.6	94.2	96.3	78.8	85.3

In the experiments with soy-bean flour the subjects ate on an average 84 grams of protein, 92 grams of fat, and 268 grams of carbohydrate per man per day. The coefficients of digestibility for the entire diet were, for protein 86.6 per cent, for fats 94.2 per cent, and for carbohydrate 96.3 per cent. The digestibility of soy-bean protein was estimated to be 85.3 per cent. Referring to pages 2 and 3 it will be noted that the digestibility of the proteins of common legumes, as shown by numerous studies made by well-known investigators, is noticeably lower than this. It is quite possible that the method of preparation and of cooking may affect the digestibility to some extent, since in grinding the press cake the cells are without doubt quite thoroughly broken up. However, in those studies in which peas were served in the form of a purée the cells were also very thoroughly broken. The digestibility of soy-bean protein (85.3 per cent) compares very favorably with that of the common cereals.

Of the 84 grams of protein eaten daily 82 grams were supplied by the soy-bean biscuits. Since approximately 85 per cent of the total protein of the biscuits was soy-bean protein, the subjects ate on an average 70 grams of soy-bean protein daily. Inasmuch as none of the subjects reported any physiological disturbances as a result of this diet, it appears that soy-bean protein is well tolerated by the human body.

The results of the experiments in general indicate that protein supplied by soy-bean press cake (ground to flour) is well assimilated and is too valuable to be overlooked as a human food.

THE DIGESTIBILITY OF PROTEIN SUPPLIED BY PEANUT PRESS-CAKE FLOUR.

As previously noted on page 13, two types of peanut flour were used in these tests, namely, one made by grinding the press cake resulting from the expression of oil from roasted, degermed peanuts, and the other by grinding the press cake remaining after the expression of oil from raw shelled peanuts from which the red skin had not been removed. The roasted peanut flour was of a golden yellow color and that from the raw peanuts was of a decidedly red tinge. Seven experiments were made with flour made from roasted peanuts and four with flour made from raw peanuts. In the first series of experiments the "flour mixture" used for making the biscuits consisted of two parts wheat flour and one part peanut flour (roasted peanuts), and in the second series the "flour mixture" consisted of equal parts of wheat flour and peanut flour (raw peanuts). Since the same men served as subjects and uniform experimental conditions were maintained for both series, the results obtained should be directly comparable.

EXPERIMENTS WITH FLOUR MADE FROM ROASTED PEANUTS.

The results obtained in the seven experiments in which peanut flour made from roasted nuts was studied are reported in the following tables:

Data of digestion experiments with flour made from roasted peanuts in a simple mixed diet.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 618, subject P. K.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Biscuits containing peanut flour.....	1,229.0	333.9	168.3	101.5	572.5	52.8
Peanut oil.....	136.0			136.0		
Fruit.....	755.0	656.1	6.0	1.5	87.6	3.8
Sugar.....	281.0				281.0	
Total food consumed.....	2,401.0	990.0	174.3	239.0	941.1	56.6
Feces.....	29.0		10.9	6.1	8.4	3.6
Amount utilized.....			163.4	232.9	932.7	53.0
Per cent utilized.....			93.7	97.4	99.1	93.6
Experiment No. 619, subject J. C. M.:						
Biscuits containing peanut flour.....	993.0	269.8	136.0	82.0	462.5	42.7
Peanut oil.....	89.0			89.0		
Fruit.....	1,056.0	917.7	8.4	2.1	122.5	5.3
Sugar.....	192.0				192.0	
Total food consumed.....	2,330.0	1,187.5	144.4	173.1	777.0	48.0
Feces.....	51.0		19.5	8.5	15.5	7.5
Amount utilized.....			124.9	164.6	761.5	40.5
Per cent utilized.....			86.5	95.1	98.0	84.4
Experiment No. 620, subject C. J. W.:						
Biscuits containing peanut flour.....	1,188.0	322.8	162.6	98.1	553.4	51.1
Peanut oil.....	199.0			199.0		
Fruit.....	751.0	652.6	6.0	1.5	87.1	3.8
Sugar.....	164.0				164.0	
Total food consumed.....	2,302.0	975.4	168.6	298.6	804.5	54.9
Feces.....	80.0		33.3	14.4	21.7	10.6
Amount utilized.....			135.3	284.2	782.8	44.3
Per cent utilized.....			80.2	95.2	97.3	80.7
Experiment No. 633, subject A. A. F.:						
Biscuits containing peanut flour.....	2,244.0	712.5	349.2	114.9	977.0	90.4
Fruit.....	762.0	662.2	6.1	1.5	88.4	3.8
Peanut oil.....	107.0			107.0		
Sugar.....	233.0				233.0	
Total food consumed.....	3,346.0	1,374.7	355.3	223.4	1,298.4	94.2
Feces.....	64.0		23.2	11.2	21.6	8.0
Amount utilized.....			332.1	212.2	1,276.8	86.2
Per cent utilized.....			93.5	95.0	98.3	91.5
Experiment No. 634, subject P. K.:						
Biscuits containing peanut flour.....	1,923.0	610.5	299.2	98.5	837.3	77.5
Fruit.....	485.0	421.5	3.9	1.0	56.2	2.4
Peanut oil.....	224.0			224.0		
Sugar.....	167.0				167.0	
Total food consumed.....	2,799.0	1,032.0	303.1	323.5	1,060.5	79.9
Feces.....	85.0		27.5	29.0	18.3	10.2
Amount utilized.....			275.6	294.5	1,042.2	69.7
Per cent utilized.....			90.9	91.0	98.3	87.2
Experiment No. 635, subject J. C. M.:						
Biscuits containing peanut flour.....	1,589.0	504.5	247.2	81.4	691.9	64.0
Fruit.....	869.0	755.2	7.0	1.7	100.8	4.3
Peanut oil.....	190.0			190.0		
Sugar.....	197.0				197.0	
Total food consumed.....	2,845.0	1,259.7	254.2	273.1	989.7	68.3
Feces.....	40.0		16.8	5.3	11.7	6.2
Amount utilized.....			237.4	267.8	978.0	62.1
Per cent utilized.....			93.4	98.1	98.8	90.9

Data of digestion experiments with flour made from roasted peanuts in a simple mixed diet—Continued.

Experiments, subjects, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbo-hydrates.	Ash.
Experiment No. 636, subject C. J. W.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Biscuits containing peanut flour.....	1,928.0	612.1	300.0	98.7	839.5	77.7
Fruit.....	878.0	763.0	7.0	1.8	101.8	4.4
Peanut oil.....	203.0			203.0		
Sugar.....	194.0				194.0	
Total food consumed.....	3,203.0	1,375.1	307.0	303.5	1,135.3	82.1
Feces.....	63.0		26.4	10.6	18.0	8.0
Amount utilized.....			280.6	292.9	1,117.3	74.1
Per cent utilized.....			91.4	96.5	98.4	90.3
Average food consumed per subject per day.....	915.5	390.2	81.3	87.3	333.6	23.0

Summary of digestion experiments with flour made from roasted peanuts in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of peanut protein alone.
		Protein.	Fat.	Carbo-hydrates.	Ash.	
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
618.....	P. K.....	93.7	97.4	99.1	93.6	93.5
619.....	J. C. M.....	86.5	95.1	98.0	84.4	75.0
620.....	C. J. W.....	80.2	95.2	97.3	80.7	60.7
633.....	A. A. F.....	93.5	95.0	98.3	91.5	92.9
634.....	P. K.....	90.9	91.0	98.3	87.2	86.9
635.....	J. C. M.....	93.4	98.1	98.8	90.9	92.6
636.....	C. J. W.....	91.4	96.5	98.4	90.3	87.9
Average.....		89.9	95.5	98.3	88.4	84.2

On an average the subjects ate 81 grams of protein, 87 grams of fat, and 334 grams of carbohydrate daily, which supplied about 2,445 calories. The coefficients of digestibility of these constituents supplied by the diet as a whole were found to be 89.9 per cent for protein, 95.5 per cent for fat, and 98.3 per cent for carbohydrate, indicating that the diet was quite well utilized. The above value for the digestibility of the total protein of the diet becomes 84.2 per cent for the digestibility of peanut protein alone when correction is applied for the undigested protein occurring in the accessory foods. The diet as a whole supplied 81 grams of protein daily, of which 79 grams were derived from the peanut-flour biscuits, and approximately 34 grams were obtained from the peanut flour. No physiological disturbances were noted by any of the subjects, indicating that this amount of peanut protein was well tolerated in these experiments.

In this series of experiments the subjects ate on their biscuits in place of butter peanut oil which was expressed from the blanched

peanuts from which the peanut flour was prepared. The average amount eaten was 55 grams daily; and apparently it was well digested, since the total fat of the diet—principally lard and peanut oil—was 95.5 per cent digested. This compares very favorably with the figures reported for the digestibility of lard ¹ and peanut oil ² as determined in earlier studies.

EXPERIMENTS WITH FLOUR MADE FROM RAW PEANUTS.

The data resulting from the four experiments made with peanut flour made from raw peanuts are summarized in the table which follows:

Data of digestion experiments with flour made from raw peanuts in a simple mixed diet.

Experiments, subject, and diet.	Weight of foods.	Constituents of foods.				
		Water.	Protein.	Fat.	Carbo- hydrates.	Ash.
Experiment No. 696, subject P. K.:	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>	<i>Grams.</i>
Biscuits containing peanut flour.....	1,571.0	384.4	386.9	238.2	480.0	81.5
Butter.....	337.0	37.1	3.4	286.4	.....	10.1
Fruit.....	390.0	338.9	3.1	.8	45.2	2.0
Sugar.....	224.0	.....	.....	.....	224.0	.....
Total food consumed.....	2,522.0	760.4	393.4	525.4	749.2	93.6
Feces.....	84.0	.....	35.4	15.5	20.4	12.7
Amount utilized.....	.....	.....	358.0	509.9	728.8	80.9
Per cent utilized.....	.....	.....	91.0	97.0	97.3	86.4
Experiment No. 697, subject J. C. M.:						
Biscuits containing peanut flour.....	1,168.0	285.8	287.6	177.1	356.9	60.6
Butter.....	246.0	27.0	2.5	209.1	.....	7.4
Fruit.....	795.0	690.8	6.4	1.6	92.2	4.0
Sugar.....	228.0	.....	.....	.....	228.0	.....
Total food consumed.....	2,437.0	1,003.6	296.5	387.8	677.1	72.0
Feces.....	69.0	.....	30.4	8.2	24.4	6.0
Amount utilized.....	.....	.....	266.1	379.6	652.7	66.0
Per cent utilized.....	.....	.....	89.7	97.9	96.4	91.7
Experiment No. 698, subject A. A. R.:						
Biscuits containing peanut flour.....	1,419.0	347.2	349.4	215.1	433.6	73.7
Butter.....	101.0	11.1	1.0	85.9	.....	3.0
Fruit.....	1,135.0	986.3	9.1	2.3	131.6	5.7
Sugar.....	193.0	.....	.....	.....	193.0	.....
Total food consumed.....	2,848.0	1,344.6	359.5	303.3	758.2	82.4
Feces.....	85.0	.....	37.5	11.4	23.4	12.7
Amount utilized.....	.....	.....	322.0	291.9	734.8	69.7
Per cent utilized.....	.....	.....	89.6	96.2	96.9	84.6
Experiment No. 699, subject W. E. T.:						
Biscuits containing peanut flour.....	839.0	205.3	206.6	127.2	256.4	43.5
Butter.....	69.0	7.6	0.7	58.6	.....	2.1
Fruit.....	1,208.0	1,049.8	9.7	2.4	140.1	6.0
Sugar.....	108.0	.....	.....	.....	108.0	.....
Total food consumed.....	2,224.0	1,262.7	217.0	188.2	504.5	51.6
Feces.....	45.0	.....	18.6	9.5	9.6	7.3
Amount utilized.....	.....	.....	198.4	178.7	494.9	44.3
Per cent utilized.....	.....	.....	91.4	95.0	98.1	85.9
Average food consumed per subject per day.....	835.9	364.3	105.5	117.1	224.1	25.0

¹ U. S. Dept. Agr. Bul. 310 (1915), p. 21.

² U. S. Dept. Agr. Bul. 505 (1917), p. 18.

Summary of digestion experiments with flour made from raw peanuts in a simple mixed diet.

Experiment No.	Subject.	Digestibility of entire ration.				Estimated digestibility of peanut protein alone.
		Protein.	Fat.	Carbo-hydrates.	Ash.	
		<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
696.....	P. K.....	91.0	97.0	97.3	86.4	89.4
697.....	J. C. M.....	89.7	97.9	96.4	91.7	87.6
698.....	A. A. R.....	89.6	96.2	96.9	84.6	87.3
699.....	W. E. T.....	91.4	95.0	98.1	85.9	90.5
Average.....		90.4	96.5	97.2	87.2	88.7

As indicated by the above table the subjects ate on an average 106 grams of protein, 117 grams of fat, and 224 grams of carbohydrate daily, which supplied approximately 2,370 calories. The average coefficients of digestibility of the protein, fat, and carbohydrate supplied by the diet as a whole were 90.4 per cent for the protein, 96.5 per cent for the fat, and 97.2 per cent for the carbohydrates.

Of the average amount of protein eaten daily (106 grams), 103 grams were supplied by the peanut biscuits, 65 grams being contributed by the peanut flour. This amount of peanut protein, much larger than that likely to be found in the ordinary mixed diet, was eaten without any noticeable digestive or other disturbances.

The digestibility of the peanut protein alone, estimated for peanut flour made from raw nuts, was found to be 88.7 per cent, a value which is not significantly different from the value (84.5 per cent) found for the proteins supplied by peanut flour made from roasted nuts. Accordingly it would appear from these figures and from the figures given above for the protein, fat, and carbohydrate of the peanut-cake diet as a whole that neither roasting nor the presence of the peanut skin materially affected the thoroughness of digestion.

SUMMARY OF ALL EXPERIMENTS WITH PEANUT FLOURS.

In order to compare carefully the values for the digestibility of protein, fat, and carbohydrate supplied by simple mixed diets, which include peanut flours ground from cakes from roasted and from raw peanuts, the results which have been obtained in the two series of experiments here reported have been brought together in the table following.

Summary of digestion experiments with flour made from peanuts in a simple mixed diet.

Experi- ment No.	Kind of peanut flour.	Subject.	Protein.	Fat.	Carbo- hydrates.	Ash.	Esti- mated digesti- bility of peanut protein alone.
			<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
618.....	Flour from roasted nuts.....	P. K.....	93.7	97.4	99.1	93.6	93.5
619.....	do.....	J. C. M.....	86.5	95.1	98.0	84.4	75.0
620.....	do.....	C. J. W.....	80.2	95.2	97.3	80.7	60.7
633.....	do.....	A. A. F.....	93.5	95.0	98.3	91.5	92.9
634.....	do.....	P. K.....	90.9	91.0	98.3	87.2	86.9
635.....	do.....	J. C. M.....	93.4	98.1	98.8	90.9	92.6
636.....	do.....	C. J. W.....	91.4	96.5	98.4	90.3	87.9
	Average.....		89.9	95.5	98.3	88.4	84.2
696.....	Flour from raw nuts.....	P. K.....	91.0	97.0	97.3	86.4	89.4
697.....	do.....	J. C. M.....	89.7	97.9	96.4	91.7	87.6
698.....	do.....	A. A. R.....	89.6	96.2	96.9	84.6	87.3
699.....	do.....	W. E. T.....	91.4	95.0	98.1	85.9	90.5
	Average.....		90.4	96.5	97.2	87.2	88.7
	Average of all tests.....		90.1	95.9	97.9	87.9	85.8

Considering the experiments with peanut flour as a whole it would seem fair to assume that the average data obtained for the digestibility of peanut protein should be sufficient for quite general application, since a total of eleven different tests was made with six different subjects and two different types of peanut flours. Considering the ration as a whole or considering the peanut protein alone, the coefficients of digestibility obtained with the two types of peanut flour are in close agreement. The average coefficients of digestibility for the diet as a whole—90.1 per cent for protein, 95.9 per cent for fat, and 97.9 per cent for carbohydrates—indicate that the experimental diet was, for all practical purposes, as well utilized as the ordinary mixed diet, the coefficients of digestibility¹ of which have been found to be 92 per cent for protein, 95 per cent for fats, and 97 per cent for carbohydrates. These figures would seem to indicate that peanut flour is itself well assimilated and that it did not exert any unfavorable effects upon the digestibility of the other foods included in the diet.

Comparing the average values obtained for the digestibility of peanut protein alone in the individual experiments it is found that peanut protein is 85.8 per cent digested, a figure lower than that of milk, meat, or egg proteins, about equal to those of cereal proteins, and somewhat higher than that of the common legumes. From the previously published data summarized above and the results of these experiments it appears that the peanut supplies a protein which yields essential amino acids, is well tolerated by the human body, and is very well digested. In view of these facts it seems that peanut flour prepared from high-grade press cake may well assume an important rôle in the human dietary.

¹ U. S. Dept. Agr. Bul. 142 (1902), p. 26.

GENERAL CONCLUSIONS REGARDING THE VALUE OF SOY BEAN AND PEANUT FLOURS AS FOOD.

Soy beans and peanuts are classed as a "sure crop," and both yield valuable products (press cakes) whose chief use at present is said to be for stock feeding. The boll weevil has made the growing of cotton unprofitable in some sections of the South. As a result, during the last season or two, the culture of soy beans and peanuts has increased with unusual rapidity. This situation, coupled with the present great demand for oils, has caused many of the cotton-seed-oil millers to utilize their machinery for pressing soy beans and peanuts. The resulting soy-bean and peanut press cakes when ground yield a flour very rich in protein and, as compared with cereal flours and meals, fairly rich in fat.

Chemical analyses reported by previous investigators of glycinin and arachin, soy-bean and peanut proteins, show that both, by hydrolysis, yield lysine and tryptophane, two amino acids recognized as essential for growth and maintenance.

Investigators studying the biologic value of these proteins by experiments with laboratory animals have shown that soy-bean and peanut proteins when employed as the sole source of protein in an otherwise adequate diet support in a satisfactory manner the normal body processes of growth, maintenance, and reproduction.

In view of these facts it seemed highly desirable to study the digestibility of the proteins supplied by soy-bean and peanut flours prepared by grinding press cakes obtained by the expression of oil from clean sound soy beans and peanuts.

The experiments here reported were made with normal young men students engaged in moderately active pursuits. The soy-bean and peanut flours were eaten in the form of a well-known type of "quick bread" or "biscuit" as a part of a simple mixed diet. None of the subjects reported any digestive or other physiological disturbances in connection with these diets, indicating that as regards the time and method of cooking, the soy-bean and peanut flours were satisfactory.

The figures, 85 per cent for the digestibility of soy-bean protein contained in ground cake and 86 per cent for the digestibility of peanut protein present in ground cake, indicate a very satisfactory utilization of these proteins by the human body. If allowance has been made for that portion of the fecal nitrogen which resulted from epithelial cells and bacteria instead of including it in the undigested residues of the soy beans and peanuts, the coefficients of digestibility of soy-bean and peanut proteins would have been somewhat higher.

The figures obtained for the digestibility of the proteins supplied by soy-bean and peanut press-cake flours compare very favorably with those obtained for cereal proteins and are somewhat higher than

those obtained for some other legume proteins. Perhaps the difference between the digestibility of the soy-bean and peanut proteins as shown by these experiments and the digestibility of the common legumes reported by other investigators is due in part at least to the soy bean and peanut having been finely ground. It is hoped that additional experiments will give more data on this point.

No attempt was made to ascertain the limit of tolerance for soy-bean and peanut flours when included in a simple mixed diet, but since in seven experiments with soy beans the subjects ate an average of 70 grams daily of soy-bean protein and in four experiments with peanut flour the subjects ate an average of 65 grams of peanut protein daily without any observed symptoms of physiological disturbance, it should be very evident that these proteins are tolerated by the human body in amounts in excess of those which are likely to be found in the ordinary mixed diet.

Since in household economy the soy-bean and peanut flours would be used to supplement wheat or other cereal flours, and since numerous investigations of the value of soy-bean and peanut proteins for food purposes indicate that these proteins have a nutritive value nearly if not quite equivalent to that of meat, milk, and egg proteins, it would seem that these flours could be very properly classed as both wheat and meat substitutes.

From these facts it is very evident that it is highly desirable to use for human food such soy-bean and peanut press cakes, by-products of the oil mills, as can be properly prepared for food purposes rather than to continue to use them exclusively for stock feeding and fertilizing purposes.

The data obtained in this and other investigations give sufficient evidence to justify the belief that soy-bean and peanut flours, rich in proteins that are well digested and of high biologic value, should prove especially valuable additions to the human dietary.

PUBLICATIONS OF U. S. DEPARTMENT OF AGRICULTURE RELATIVE TO FOOD AND NUTRITION.

AVAILABLE FOR FREE DISTRIBUTION BY THE DEPARTMENT.

- Meats: Composition and Cooking. By Chas. D. Woods. Pp. 31, figs. 4. 1904. (Farmer's Bulletin 34.)
- The Use of Milk as Food. By R. D. Milner. Pp. 44. 1911. (Farmers' Bulletin 363.)
- Care of Food in the Home. By Mrs. Mary Hinman Abel. Pp. 46, figs. 2. 1910. (Farmers' Bulletin 375.)
- Economical Use of Meat in the Home. By C. F. Langworthy and Caroline L. Hunt. Pp. 30. 1910. (Farmers' Bulletin 391.)
- Cheese and Its Economical Uses in the Diet. By C. F. Langworthy and Caroline L. Hunt. Pp. 40. 1912. (Farmers' Bulletin 487.)
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- The Detection of Phytosterol in Mixtures of Animal and Vegetable Fats. By R. H. Kerr. Pp. 4. 1913. (Bureau of Animal Industry Circular 212.)
- Some American Vegetable Food Oils, Their Sources and Methods of Production. By H. S. Bailey. (Yearbook Separate 691.)

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- Studies on the Influence of Cooking upon the Nutritive Value of Meats at the University of Illinois, 1903-4. By H. S. Grindley, Sc. D., and A. D. Emmett, A. M. Pp. 230, tables 136. 1905. (Office of Experiment Stations Bulletin 162.) Price, 20 cents.
- Studies of the Effect of Different Methods of Cooking upon the Thoroughness and Ease of Digestion of Meats at the University of Illinois. H. S. Grindley, Sc. D., Timothy Mojonner, M. S., and Horace C. Porter, Ph. D. Pp. 100, tables 38. 1907. (Office of Experiment Stations Bulletin 193.) Price 15 cents.
- Digestibility of Some Animal Fats. By C. F. Langworthy and A. D. Holmes. Pp. 23. 1915. (Department Bulletin 310.) Price, 5 cents.
- Digestibility of Very Young Veal. By C. F. Langworthy and A. D. Holmes. Pp. 577-588. 1916. (Journal of Agricultural Research, 6 (1916), No. 16.) Price, 5 cents.
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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 718

Contribution from the Forest Service
HENRY S. GRAVES, Forester.



Washington, D. C.

December 17, 1918

SMALL SAWMILLS: THEIR EQUIPMENT, CONSTRUCTION, AND OPERATION.

By DANIEL F. SEEREY, *Logging Engineer.*

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OBJECT OF THE BULLETIN.

Running a portable sawmill is no longer an easy occupation. The more accessible timber in the West has mostly been cut out or burned, and to-day the principal stands are far back in the hills, making logging and milling expensive as well as strenuous work. Profitable operation calls for first-class logging equipment and modern mills, and for good business ability, skill, and hardihood on the part of the operator. Physical weaklings are more out of place in logging work than in any other kind of virile employment. Mere physical strength, however, is not in itself sufficient. A successful logger needs to be "strong" in the head as well as in the muscles.

This bulletin offers to portable sawmill operators suggestions regarding methods of organization, milling, and logging which have

been proved by experience to give the best results. It is meant particularly for operators in National Forest timber, but should be useful to other owners of portable mills where conditions are like those in the National Forests.

GENERAL SUGGESTIONS FOR PORTABLE SAWMILL OWNERS.

LOOK BEFORE YOU LEAP.

Before purchasing a new mill or moving an old one to a new location, an operator should carefully inform himself regarding the following points:

- Amount of timber available for his operations.
- Kinds and grades of lumber the timber will produce.
- Density of the stand and conditions governing its cutting and removal.
- Method of marking timber to be cut.
- Method of scaling and lengths allowed for trimming.
- Penalty scale for broken trees and logs left on the ground.
- Length of time each year during which operations can be profitably carried on, and annual cut.
- Labor and supplies required and working capital necessary to finance the job.
- Margin of profit on which the business can be operated.
- Stumpage prices and how obtained.
- Payments and manner of making them.
- Logging costs and methods.
- Number of teams available for logging, for delivering lumber, and for hauling supplies.
- River and road improvements necessary.
- Brush disposal, and cutting and utilization of defective timber.
- Capacity, equipment, and power of mill.
- Milling or manufacturing costs.
- Distance to market and condition of roads.
- Capacity of market and prices for different grades.
- Competition.
- Possibility of establishing a small retail yard.
- Amount of lumber which market conditions require to be carried in stock.
- Market for by-products, such as mine timbers, railroad ties, telephone, telegraph, and power poles, field posts, cordwood.
- Responsibility for fire.
- Sanitary regulations.

If there is doubt about your ability to meet any of the conditions affecting the operation, go slow. It is a great deal better to find out beforehand that the chances are against success than to discover this fact only after you are in and can't get out.

CAPITAL REQUIRED.

Insufficient working capital is one of the prime causes for the failure of a small sawmill to make a reasonable profit. Even in a small operation considerable working capital is necessary for current expenses. Money must be available to pay for the equipment of the mill, the wages of the crew, the building of sheds, tracks, yard, bunk and cook houses, stables, and blacksmith shops, and for current expenses and repairs. Money is needed to carry a stock of lumber on the mill yard. These items of expense should be worked out in advance, and when money is not available at reasonable rates of interest, the prospective operator will be prudent if he resists the desire to become a sawmill owner. While it is true that a few have made a success from a very slender financial start, the chances of doing this are so remote that to embark in the sawmill business without the requisite capital is more of a gamble than a legitimate business proposition. A junked mill with an accompaniment of a few old axes and broken-down teams and harness, a rusty cross-cut saw or two, and, worst of all, several big bills and perhaps a mortgage, make a poor showing after several years of hard work.

CREDITS.

The unwarranted extension of credit is an almost universal practice among small operators, and usually results in disaster. The successful mill man sells for cash or negotiable paper. It is a common practice, however, to sell a load or two of lumber on time right along, even though the man who sells it owes his employees for labor or the merchant for supplies. If such a man is not mighty alert, he will soon find himself badly in arrears with his payments. Should that come about, the end of his career as a sawmill operator is in sight.

COST KEEPING.

The most important step in the operation of a sawmill is the opening of a simple set of books in which is recorded faithfully the cost of everything relating to the business. In the absence of such a record an operator is sailing on an unknown sea "without chart or compass." Yet, except in a very few cases, this necessary side of the business is entirely neglected. In a long experience with portable mill owners it was not until quite recently that the writer met one who gave it proper attention.

No elaborate system of cost keeping is needed by the small operator. All that is required is some simple form of accounting by which he can tell the value of his investments, the cost per thousand feet for logging and milling, the stumpage cost per thousand, the cost of repairs and new investments, the depreciation on logging and milling

equipment, and the losses incidental to his business. Over against this should appear the value of the lumber sold by grade and the value of the yard stock by grade. Keeping a record of this kind is something that the average mill man is thoroughly competent to do himself, or he can get some member of his family to do it for him. A salaried bookkeeper is neither necessary nor desirable; he would cost too much. Once started on a simple system of cost keeping, the operator will, it is safe to say, be so much interested in the knowledge and insight which it gives him of his business that he will need no urging to keep it up.

While on the subject, it is pertinent to remind operators that hay, grain, vegetables, meat, etc., which are produced on their ranches and consumed on their logging operations should be charged against the sawmill account at the same price they would have cost if ordered from a storekeeper. The operator's own time, as well as that of his team while employed on the logging job, should also be charged to operating expenses. Very few sawmill men do this, the general idea seeming to be that if the business pays for the hired help and merchandise actually purchased from the store it is doing all that can be expected of it. Many operators seem to think that because they have made no money in the past, there is no possibility of making a better showing in the future. As long as operators have this feeling, it is morally certain that their condition will remain unchanged. Only when the men in the industry realize that they are engaged in a pursuit which calls for the best that is in them, and that increasing profits will reward their efforts, will the portable mill business take and hold its proper place among the staple industries of the country.

ORGANIZATION.

There are two ways in which an operator can organize his logging and milling work to obtain satisfactory results and at the same time know approximately how much each operation costs. One way is to keep the logging distinct from the milling, preferably carrying on the former during fall or winter, provided snow is not too deep. By this plan sufficient logs can be piled up in the mill yard or skidded up along the main road to keep the mill running during the season. The other and less desirable way is to take the entire crew into the timber and cut logs ahead for the season's run, afterwards working enough skidding and hauling teams to keep the mill supplied with logs.

The usual plan, however, is to log for a few days and mill for a couple more. This plan is neither economical nor efficient, for mill workers are very rarely good loggers and loggers are very rarely good millmen. Moreover, the axes, saws, and logging equipment get mislaid or are thrown aside after a few days' use. No one set of men is

responsible for keeping them safe or in proper trim, and so valuable time is lost in assembling the equipment and getting it in working condition.

MILL SITE.

A number of points have to be considered in connection with the location of the mill. It should be near the water supply, but the buildings, and especially the toilets, should be so placed as to prevent any danger of the water becoming polluted. At the same time the mill should be at a point in the timber where there is from 500,000 to 1,000,000 feet of stumpage available for one setting, and where it will not be necessary to haul or skid the logs over long distances or uphill. Because a mill is small and portable is no reason why it should be moved very often, unless there is a good economic reason for doing so. Select a central site in the first place, where water and other conditions are favorable, and move only when the cost of moving, building new roads and camps, etc., can be saved by a shorter haul. The operator who moves his mill without figuring the attendant cost is likely to find that, though his mill may be small and portable, the expense of a new setting will not be small or very profitable in a financial way.

Yard and piling space must be provided for the lumber and slab piles, and a right of way for from 700 to 800 feet of narrow-gauge track on which to run the lumber from the mill to the yard. There must be a landing deck for logs, with log decks and skidways, and provision must be made for the economic handling of sawdust and bark. Convenient locations must be found for the bunkhouse and the camp dining room and storeroom. Toilets and covered refuse pits are other essentials.

A rough ground plan of the proposed plant will materially assist the operator in selecting sites for the different buildings. In some instances tents can be substituted for wooden structures. Dry wood for domestic use is sometimes an important consideration. The entire area round the mill and buildings should be cleared of brush and débris and kept cleared. Two or three milch cows and a few hogs and poultry can be maintained around a small mill at very little expense.

LABOR.

It is essential for the success of a small mill operation that the logging crew should be made up of experienced men. Green hands may succeed fairly well around the mill handling lumber or sawdust, but the woodsmen must be trained or else they will not do enough effective work to pay for their board. Green hands attempting to fell, skid, load, and haul logs are only about 25 per cent efficient, without reckoning the loss from broken timber, split trees, etc.,

which if taken into account would reduce their efficiency close to zero. The custom of trading lumber for inexperienced labor, so prevalent in many places, should never be practiced by the small operator.

A real knowledge of how to handle horses is very essential in logging. Thousands of dollars' worth of good horseflesh is ruined by ill-tempered, incompetent teamsters. No part of the operator's investment needs closer supervision than the hauling. A poor teamster is poison (I know of no more expressive term) to a good team. An operator will save money by keeping his horses idle in the barn, no matter how badly their services are needed, rather than allow a brainless teamster to pound them through the timber and over rocks, stumps, and mud holes. Discharge such a person at once. Teams when properly handled will be 100 per cent efficient all the time and thrive.

High wages do not always secure the service of competent labor, particularly in woods work. One gang of sawyers may cut the same amount of board feet in logs as another gang, and yet may cut their logs with such a disregard of correct lengths and of crooks and with such an indifference as to how the trees are felled for skidding purposes that the value of their labor may be only 50 per cent as much as that of the other crew, who do their work as it ought to be done.

The millman who neglects to supervise his operations rigidly is surely preparing the way to financial disaster. An operator usually works hard at some particular job, such as sawing, and leaves the rest of the work to run itself. His proper place is "bossing the job," and if he does that thoroughly he will have his hands full. In order to instruct men in woods work, the operator must understand it himself. If he lacks this knowledge it would be wise for him to keep out of the portable-mill business or else hire a competent man to run it for him.

Clean, wholesome living and sleeping quarters for the men, as well as properly cooked food, deserve close attention—a good deal more attention, in fact, than is usually bestowed upon them. "Sour dough" grub and rough living may sound very romantic in a cheap novel, but when actually practiced they fail to bring results. Pay the men good wages and feed them well, and see that they earn it. Always have money on hand to pay off men if they quit or you discharge them.

Make it very plain that you want value for every cent you pay in wages or in board. Tolerate no "deadheads" around your camp. Be boss yourself or delegate the job to some one who is qualified to fill the bill. Do not make your camp a dumping ground for all your male relatives. You are supposed to be running a sawmill—not a rest cure.

In short, inject a lot of energy and vigor into the business, or leave it to some one who can.

COMMISSARY.

Every operator should keep a small supply of dry goods in stock for the use of his men, and also such articles as tobacco, matches, pipes, medicine, and writing pads and pencils. Old magazines and books are easily obtained and are eagerly read. The supplies enumerated should be bought in bulk or by wholesale, in order to cover the cost of freight and handling. Kerosene and lubricating oils should be purchased by the barrel, and enough camp supplies, such as flour, feed, pork, potatoes, hay, groceries, and canned stuff, should be kept in stock to avoid the necessity of sending a man and team to town every week. The item of supplies is an important one to the success of the job and should be handled economically.

MARKETING.

Every town and village on a railroad has at least one retail lumber yard, and very often more than one. It is one of the first institutions to be established after the advent of the railway. In towns and villages remote from the railway, however, lumber yards are seldom in evidence, although there may be and usually are half a dozen portable mills hidden away in the hills in the vicinity. Yet a lumber yard is as much a necessity and could command as much business in many of these remote communities as the one or two yards in the railway town.

Right here is an opportunity for wide-awake portable mill owners to establish themselves in the lumber business. The surprising thing is that so few have taken advantage of it. If a rancher needs a load of lumber and sees a yard right in town he will buy material and take it home with him; whereas if he knows that he has to drive to the mill 10 or 12 miles in the hills over a wretched road, and is not sure of getting what he wants when he arrives there, he will naturally put off a disagreeable job as long as he can. Eventually, if he has business in the railroad town, he will purchase from the retail yard there. An occasional short item in the local paper telling the public something about the activities of the local sawmill and the amount of lumber turned out daily, with the stock on hand, makes interesting reading for the local public, particularly for people who need lumber.

There are scores of towns and villages in the inter-mountain country where such opportunities exist to-day. Yard space would cost very little and teamwork is cheap, and the millman who takes a little pains in milling and grading his lumber and putting it up in neat piles will soon have his mill running steadily to keep up with

the demand. There is little to be gained in sawing out a lot of lumber and keeping it hidden away in the hills. For every man, woman, and child in the United States 375 feet of lumber is used annually; in new States three or four times as much. Montana, for example, uses 1,234 feet per capita, and it is a moderate estimate that a community of 500 people will use up a quarter of a million feet annually. A small mill operator who opens a yard and keeps 100,000 feet of lumber in stock, along with a moderate amount of shingles, lath, and building material, can establish a remunerative business very easily. Be it understood that lumber in this sense means lumber that is properly sawed, surfaced (when necessary), edged, trimmed, graded, air dried, and properly piled. You can not run a successful lumber yard with rubbish anywhere.

The heaviest demand in newly settled communities is for low-grade lumber, viz, No. 3 common and dimension, the very class of material which the portable mills can supply most readily. The upper grades will always find a remunerative market. A small mill, if properly handled, can successfully hold a competitive market for low-grade lumber and dimension against similar products produced in a large mill and shipped into the local market.

GRADING LUMBER.

The necessity for grading the product of small mills can not be emphasized too strongly or too often. Every millman is able to distinguish between good and bad, rotten and sound lumber, and what sort of a log is best adapted for inch lumber and what for plank, dimension, finish, and so on. But when it comes to being able to tell at a glance what defects in a board causes it to grade No. 1 common instead of inch finish very few can make an intelligent distinction, yet those men have been handling such lumber perhaps a lifetime. They have simply neglected to use their powers of observation.

The Western Pine Manufacturers' Association of Spokane, Wash., issues free a little booklet containing the rules for the grading of pine, fir, and larch, which is distributed by their secretary to anyone interested. To a man handling lumber every day this little book will be invaluable. To have lumber to sell and no grading rule to sell it by is a condition that spells certain loss for the sawmill owner. If he doesn't study grading himself, his son will, with the result that the boy will learn more about the lumber business in a month than his father has been able to pick up in years. There is no "royal road" to a knowledge of lumber grading—you must learn it yourself.

It sometimes happens that when an enterprising mill operator, who has adopted modern methods in milling and grading his output, is negotiating the sale of a bill of lumber with a prospective purchaser,

another operator with an old mill up in the hills will jump in and take the order away from him at a lower price. That particular bill of lumber, it is safe to predict, will be sawed in any old way, with the result that the purchaser is dissatisfied with the material he gets, and concludes that native timber is no good, and never buys any more of it. By this sort of thing the unprogressive mill operator spoils a lot of good lumber at no profit to himself. It doesn't pay to drive away future trade for the sake of a single sale. In these days men no longer have to use the roughest kind of lumber for lack of something better. They may use it once, but it is a moral certainty that they won't come back for any more. The way for an old-time operator to get and hold trade is to turn to modern methods, not to try to put another and more progressive man out of business. A new order prevails in the lumber business, and no one knows better than the small millman that there is no profit in logging along the old lines. A determined effort must be made to get out of the old rut and place the portable mill industry on a paying basis.

AUXILIARY PRODUCTS.

The demand for lumber and dimension stuff—the regular products of the mill—is always supplemented by a demand for the more finished products, such as planed lumber, siding, flooring, lath, shingles, etc., which require special machinery for their manufacture. The millman will find that he can get more for his best grades of lumber if he can furnish them as required by the local trade. Considerable waste may be saved in the utilization of short lengths and slabs, which otherwise would be lost. There is money in reducing waste when it can be partially transformed into a salable product.

SOME DON'TS FOR SAWMILL OPERATORS.

Before outlining in detail the necessary equipment for a portable mill and how it should be operated a few suggestions as to what to avoid or, in other words, what not to do may not be amiss. To mill operators:

1. If you have a market and a cutting capacity of 500,000 feet per year, do not enter into a contract with the Government or with anyone else to cut 5,000,000 feet in three years.
2. If you are financially unable to make more than \$300 in advance payments, do not sign a contract to pay \$500.
3. Do not sign a contract with the Government to cut timber on a National Forest without carefully going over the area and finding out for yourself what species of timber you are expected to cut and where it is located.
4. Do not try to fell timber with a dull, rusty cross-cut saw and wooden wedges. It won't pay.

5. Do not try to keep your axes sharp and serviceable with a rusty file. Try a grindstone.

6. Do not try to skid saw logs without skidding tongs, swamp hook, cant hook, and chain. Handspikes and hand-beam levers are out of fashion.

7. Do not try to haul saw logs on a lumber wagon. Try a heavy truck or a logging sled if you have sufficient snow.

8. Do not try to haul saw logs uphill or over rocks and brush. Build a road.

9. Work steadily and systematically. If half your crew leaves on Saturday and does not return to work until the following Tuesday, get steadier men. Blow your whistle at 7 o'clock every morning and get to work at 7, not 9.

10. Do not unload your saw logs all over the mill yard and then roll them over rocks, boulders, slabs, brush, and mud holes with a handspike. Build a downhill skidway in front of the carriage, and the logs will roll down by gravity.

11. If your mill can manufacture 10,000 feet per day, see that it does that every day you run it. Capacity cutting for one day during the season does not count.

12. If your boiler is old and leaky, get it repaired and inspected. A rusty, leaky boiler is likely to stop all business quite suddenly. Watch the water gauges.

13. Use dry slabs and clean water in making steam. Green slabs, dirty water, and a leaky boiler make a bad combination. Use the mud cock frequently.

14. Do not try to manufacture merchantable lumber with a dirty, rusty engine set on a rotten foundation with a shaky mandrel, rotten belting, a saw out of "true" and running at half speed under insufficient steam from a leaky boiler. It can't be done.

15. Do not expect your mill to be a profitable business if you leave your mill machinery exposed to the weather the year round. You will soon have a junk pile, not a sawmill.

16. Do not expect to get the value of your lumber if you throw it in a heap in the mill yard instead of piling it properly and grading it.

17. Do not sell your lumber on credit or on time. You have not sufficient capital to do a credit business.

18. Do not keep your accounts on a shingle or marked up on a board. A small Dr. and Cr. account book is much more satisfactory.

19. Do not try to run a sawmill, however small, by rule-of-thumb, hit-or-miss methods that your grandfather practiced. They will not work in this day and age.

20. Do not forget that this is the twentieth century and that the management and successful handling of a portable mill is a twentieth-century problem.

THE MILL AND MILLING.

If the operator is already provided with a mill, the size of his operations will depend on the power and capacity of that mill. If he plans to purchase a new mill, he should figure on one with the power, capacity, and equipment necessary to meet the requirements of his capital, his market, and his logging equipment. Lack of sufficient power, even for driving the saw, is a common handicap for small mills. An effective 25-horsepower engine will, if properly handled, keep a circular saw working to capacity and at the same time will run a small planer and edger.

The type of mill in most general use in Forest Service District 4 is one cutting from 2,000 to 20,000 feet per day. The following discussion, therefore, will be confined to two classes of this type, one cutting from 2,000 to 10,000 feet per day and a heavier one cutting from 10,000 to 20,000 feet per day. The smaller mill will be called Class A, and the larger, Class B.

Sawmills are generally classified as right and left hand mills, according to whether the log passes to the right or to the left of the saw, viewed from the front. In ordering equipment for an old mill it is always necessary to specify whether the equipment is needed for a right or left hand mill.

Portable mills are usually equipped with rack and pinion or cable drive, and friction or belt feed or a combined belt and friction feed. Shotgun feed is not used in small mills. The variable friction feed is so called because the sawyer can vary the feed to correspond with the power or the size and species of timber to be cut, easing down on knots and frozen timber and increasing the feed at will. With the same power a variable friction-feed mill is said to cut from 25 to 40 per cent more than a belt-feed mill. There are no belts or springs to break or give trouble. The belt feed is a combination of belt and flat face frictions so arranged that the feed and gig back frictions are continuously driven in opposite direction by an endless belt direct from the mandrel. A single lever operates the feed and gig back by shifting the bull wheel from one friction to the other. The shaft of the bull wheel has a pinion on the opposite end which operates the wire cable drum, doing away with all intermediate gears and securing a strong direct drive for the carriage. The friction shafts have babbitted boxes with screw adjustment to take up the wear in the frictions, and a substantial idler is provided to keep the endless feed belt always tight. Wire cable or rack and pinion drum can be used on both belt-feed and friction-feed mills.

"Never buy anything because it is cheap" is a form of advice that applies very particularly to a sawmill. Going a little further, it might be laid down as an excellent business maxim: Never buy an old second-hand mill, no matter how cheap it can be purchased. Re-

ardless of type or make, however, a mill will turn out to be a liability rather than an asset unless it is set up properly and kept in good running order, and the work conducted on a business basis.

The word "portable" as defined in the dictionary means "capable of being borne or carried, easily transported, conveyed without difficulty." The average portable mill owner, however, seems to take this definition too literally, for when he purchases a new mill, or moves to a new site, he pays as little attention to setting it up or lining the machinery properly as he would in the case of a thrashing engine or a steam plow. The usual procedure is to clear off a level space of ground, set down the engine and boiler and block them up a little, adjust the belting, get up steam, and start the saw. The moving and setting up is not taken seriously. Regardless of the length of time a portable mill is to remain on the same site, the engine bed should be solid, the belting properly adjusted, the engine, sawmill, and carriage properly lined up and housed and all working parts oiled and the shafting in line and all parts in good working order. Otherwise it is impossible to manufacture good lumber.

In general, the life of a portable mill may be placed at from 12 to 15 years. One hundred and fifty days is the maximum time it is in active operation each year, so that, if not properly cared for, a portable mill may be said to "rust out" faster than it wears out.

REGULAR EQUIPMENT.

CLASS A.

Following are the various parts and equipment of a class A mill complete and their cost in 1916. Since the entrance of the United States into the war, prices have fluctuated to such an extent as to make it impractical to give those likely to be in effect when this bulletin is issued. It has been thought best, therefore, to give 1916 prices throughout as a basis for estimates.

Sawmill (husk and carriage).....	\$254. 00
Sawdust conveyors, 25-foot	35. 00
48-inch chisel-tooth circular saw, 8 gauge.....	62. 00
60-inch solid-tooth circular saw, 7 gauge.....	82. 00
Engine and boiler, 15 horsepower.....	776. 00
Pony edger.....	145. 00
Trimmer.....	280. 00
Shingle machine.....	160. 00
Lath mill and bolter.....	200. 00
Shingle buncher and packer.....	10. 00
Axes, cant hooks, shovels, wheelbarrows, etc.....	20. 00
Chisel tool files, dozen.....	5. 00
Total	2, 029. 00
Discount 20 per cent.....	405. 80
	1, 623. 20

The equipment of the sawmill usually consists of—

Husk frame, 7 by 3 feet, built of $3\frac{1}{2}$ by $7\frac{1}{2}$ inch timbers.
 Variable-friction feed.
 Steel mandrel, $2\frac{3}{4}$ inches by 4 feet 4 inches.
 Board roll and spreader wheel and saw guide.
 Carriage 16 feet long and 26 inches wide, of $3\frac{1}{2}$ by $5\frac{1}{2}$ inch timber.
 Feed rack, 22 feet long.
 Four trucks with 6-inch wheels and $1\frac{1}{8}$ -inch steel axles.
 40 feet of V and flat rolled steel track.
 Two head blocks, opening 34 inches, with duplex dogs.
 Ideal set works with quick receder.
 14-inch polished-steel set shaft.

There is also furnished a mandrel pulley up to 24 inches diameter, belt tightener, foundation bolts, cant hook, oil can, and wrenches for rack and pinion-carriage drive. Also trackway timbers bolted together with steel track attached.

The price of a sawmill so equipped, as shown in the preceding cost statement, is \$254 f. o. b. Chicago. The manufacturers allow 15 per cent discount on time, and 20 per cent for cash. The total shipping weight is 2,550 pounds. Way timbers are 450 pounds extra.

Extra equipment:

Manila-rope drive with sheaves, add.....	\$10.00
Wire-cable drive, add.....	25.00
For each additional foot of carriage, add.....	3.50
For each additional foot of set shaft, add.....	.60
Trackway timbers, if not wanted, deduct.....	16.00
Belt tightener, if not wanted, deduct.....	13.00

A top-saw attachment is too heavy for this type of mill. All mandrels are made for saws with 2-inch center hole and two $\frac{5}{8}$ -inch pinholes on 3-inch circle, and are adapted to any power from 6 to 15 horsepower. This outfit can cut 2,000 feet per day with a 6-horsepower engine, or from 7,000 to 8,000 feet per day with a 15-horsepower engine. It will carry a saw up to 52 inches and logs up to 36 inches diameter.

CLASS B.

The class B mill is heavier and of larger capacity than the class A mill, and has an independent rack beam near the center of the carriage. It is adapted to engines of from 15 to 40 horsepower, and will cut from 10,000 to 20,000 feet per day. Saws up to 60 inches may be used. The headblocks will open to receive a log as large as 54 inches in diameter. The parts and equipment are—

Sawmill	\$454
Sawdust conveyors.....	35
48-inch inserted-tooth circular saw, 8 gauge.....	62
60-inch solid-tooth circular saw, 7 gauge.....	82

Engine and boiler, 25 horsepower-----	\$1,053
Pony edger-----	145
Trimmer-----	280
Planer-----	169
Slash saw-----	60
Shingle machine-----	160
Lath mill and bolter-----	200
Shingle buncher and packer-----	10
Tools, axes, cant hooks, shovels, etc-----	20
Inserted-tooth files, per dozen-----	6

Total-----	2,741
Discount 20 per cent-----	548

2,193

The equipment of the sawmill consists of—

Husk frame 8 feet 6 inches by 4 feet built of $4\frac{1}{2}$ by $11\frac{1}{2}$ inch timbers.

Variable-friction feed.

Steel mandrel $2\frac{15}{16}$ inches by 5 feet 6 inches long.

Mandrel pulley 24 by 12 inches.

Board roll, spreader wheel, and saw guide.

Carriage 24 feet long, 40 inches wide, timbers $5\frac{1}{2}$ by $5\frac{1}{2}$ inches.

Feed rack 32 feet long.

Six trucks with 10-inch wheels and $1\frac{11}{16}$ -inch steel axles.

Fifty-six feet of V and flat rolled steel track.

Two head blocks opening 48 inches with Grant duplex dogs.

Twenty feet polished-steel set shaft.

Trackway timbers framed and bolted together in sections with steel track attached, belt tightener, foundation bolts, cant hook, oil can, and wrenches.

Rack-and-pinion carriage drive.

Saw not included. Weight 5,250 pounds.

The extras are—

Manila-rope drive with sheaves, add-----	\$10
Wire-cable drive with carriage, add-----	36
Carriage, each additional foot, add-----	6
Set shaft, each additional foot, add-----	1
Top saw attachment, add-----	80
Trackway timbers, if not wanted, deduct-----	20
Belt tightener, if not wanted, deduct-----	14
Sawdust conveyor fixtures (weight, 142 pounds).	

Top mandrel is $1\frac{15}{16}$ inches diameter and made for standard saws with 2-inch hole and $\frac{5}{8}$ -inch pin holes on 3-inch circle. Weight, 1,075 pounds.

The average cost of setting up the mill is—

Mill (with machinery on the ground)-----	\$300
Housing-----	250
Boarding and sleeping camps-----	200
Total-----	750

AUXILIARY EQUIPMENT.

EDGERS.

A 33-inch pony gang edger with a capacity of from 5,000 to 11,000 feet per day has two saws with single-pressure roll, and cost in 1916—

With solid-tooth saws.....	\$145
With inserted-tooth saws.....	175

A discount of 40 per cent is allowed from these prices. Specifications for edgers of this size are—

Floor space, 18 feet 6 inches by 48 inches.

Width inside, 33 inches.

Guide adjustment, 4 inches.

Mandrel pulley, diameter, $1\frac{1}{8}$ inches.

Mandrel pulley, dimensions, 8 by 8 inches.

Saws, diameter, 14 inches.

Speed, revolutions per minute, up to 2,000.

Feed belt, 8 feet long, 4 inches wide.

Maximum opening between saws: Two-saw edger, 24 inches; three-saw edger, 20 inches.

Weight: Single roll, 1,300 pounds; double roll, 1,400 pounds.

PLANER.

Planers are built in two sizes, to surface up to 16 inches and 20 inches wide and from $\frac{1}{4}$ inch to 6 inches thick, with or without countershaft, as ordered. No belting is furnished. Feed belts require $13\frac{1}{2}$ feet of $1\frac{1}{2}$ -inch belting.

One pair planer knives, weight 745 pounds:

16-inch machine with countershaft..... \$152

20-inch machine with countershaft..... 169

Pony planer, weight 1,700 pounds:

20-inch..... 275

24-inch..... 325

Planer and matcher..... 360

Prices are subject to discount of 20 per cent, Chicago.

SAWDUST CONVEYORS.

Sawdust conveyors are labor-saving devices that constitute a good investment. The standard 25-foot conveyors consist of the necessary sprocket wheels, bevel gears, sprocket and gear shafts, boxes, collars, 50 feet of carrier chain with conveyor attachments, and 10 feet of drive chain.

Price of 25-foot conveyors as described.....	\$35.00
Price per foot extension.....	\$0.45
Longest run recommended.....feet..	60
Approximate weight.....pounds..	150

TWO-SAW TRIMMER.

No. 1 machine, for boards from 6 to 16 feet, weight 2,650 pounds-----	\$280
No. 2 machine, for boards from 6 to 18 feet, weight 2,750 pounds-----	300
No. 3 machine, for boards from 8 to 20 feet, weight 2,850 pounds-----	320
No. 4 machine, for boards from 8 to 24 feet, weight 3,110 pounds-----	340

CUT-OFF SAW.

Timbers in main frame $3\frac{1}{2}$ by $3\frac{1}{2}$ inches.

Timbers in table frame 2 by 4 inches.

Mandrel (steel) $1\frac{1}{8}$ inches for saw with $1\frac{1}{4}$ inch hole.

Mandrel pulley 4 by 4 inches.

Size of saw, 20 inches. (Any size can be used from 18 to 24 inches.)

Floor space 4 by 10 feet.

Shipping weight, 430 pounds. Price f. o. b. Chicago, \$70. Iron parts only, no saw. Discount 22 per cent.

LATH MILL AND BOLTER.

Frame, 8 feet long, 37 inches wide, and 27 inches high.

Lath, saw, 10 inches; bolter saws, 22 inches.

Driving pulley on each mandrel, 8 by 8 inches.

Speed of lath saws, 2,700; bolter, 1,400.

Weight of combined machine, 1,050 pounds.

Complete with 3 lath saws and bolting saw, \$200. Discount 22 per cent, f. o. b. Chicago.

GANG LATH MACHINE.

3 saws-----	\$130
4 saws-----	134
5 saws-----	138
6 saws-----	142

20 per cent discount f. o. b. Chicago.

Frame, 37 inches long, 37 inches wide, and 27 inches high.

Lath saws, 10 inches.

Driving pulley on mandrel, 8 by 8 inches.

Speed of saws, 2,700 r. p. m.

Weight, 675 pounds, net.

SHINGLE MACHINE.

Cuts 16 to 18 inch shingles with 36-inch saw, \$160; 20 per cent discount, f. o. b. Chicago.

SHINGLE BUNCHER OR PACKER.

Size of bunch, 20 inches wide, 30 inches long.

Price, \$10. Weight, 80 pounds.

Discount, 20 per cent f. o. b. Chicago.

ENGINES AND BOILERS.

TYPES AND CAPACITIES.

The usual specifications for a 15-horsepower engine and boiler suitable for a class A mill are—

Size of cylinder, 8 by 10 inches.

Revolutions per minute, 100.

Diameter of pulley, 44 inches.
 Face of pulley, 10 by 10½ inches.
 Diameter of boiler, 32 inches.
 Length of furnace, 44 inches.
 Height of furnace, 33 inches.
 Width of furnace, 26 inches.
 Number of 3-inch tubes, 26.
 Length of tubes, 78 inches.
 Shipping weight, 7,300 pounds.

The price is \$776. The following are furnished as regular equipment: Oil cups, sight-feed lubricator, steam gauge, water gauge, whistle, gauge cocks, throttle, blow-off check, stop and safety valves, smoke stack, grates, governor, belt pulleys, pet cocks and wrenches, stack and guy wires, steam and exhaust connections and injectors.

The center crank horizontal engine mounted on a water front open bottom locomotive boiler is suitable for class B mills. The engine is firmly bolted to brackets securely fastened to the shell of the boiler. It can also be detached and used separately.

The fittings and fixtures comprise grates, water column, water gauge, gauge cocks, steam gauge, safety valve, check and stop valves, whistle blow-off valve, stock and guy rods, injector attached, fly-wheel pulley, oil cups, sight-feed lubricator, throttle valve and nipples, automatic governor and belt, pipe connection between boiler and engine, and exhaust pipe; pump and heater instead of injector and spark arrester extra.

The usual specifications for a 25 or 30 horsepower engine attached to locomotive boiler, suitable for class B mills, are—

	25 horse- power.	30 horse- power.
Size of cylinder.....inches..	10 by 12	10 by 12
Revolutions per minute.....	160	190
Diameter of pulley.....inches..	24 and 52	24 and 52
Face of pulleys.....do.....	12 and 12½	12 and 12½
Diameter of boiler.....do.....	36	36
Length of furnace.....do.....	52	52
Height of furnace.....do.....	38	40
Width of furnace.....do.....	30	30
Number of 3-inch tubes.....	34	34
Length of tubes.....inches..	96	120
Diameter of smokestack.....do.....	16	16
Length of smokestack.....feet..	25	25
Size of steam pipe.....inches..	2½	2½
Size of exhaust pipe.....do.....	3	3
Diameter of shaft.....do.....	3¼	3¼

The water-front, open-bottom boiler has proved to be one of the best types. With the open bottom there is no dead water space below the grate surface, such as exists in the water-bottom boilers, to fill with mud and sediment. The open bottom permits the free discharge and easy removal of ashes, thus providing free draft, an important consideration in the case of the poorer grades of fuel such as are

used in mountain mills. The fittings and fixtures comprise grates, water column attached with gauge cocks, water gauge, steam gauge, safety valve, check valve, stop cock, whistle, blow-off valve, stack and guy rods (four times the length of the stack); injector and spark arrester extra.

The usual specifications for a 25 or 30 horsepower boiler are—

	25 horse- power.	30 horse- power.
Diameter of boiler.....inches..	36	36
Length of fire box.....do.....	52	52
Height of fire box.....do.....	38	40
Width of fire box.....do.....	30	30
Number of 3-inch tubes.....	34	34
Length of tubes.....inches..	96	120
Thickness of shell.....do.....	1/2	1/2
Thickness of furnace plates.....do.....	1/2	1/2
Thickness of tube sheets and heads.....do.....	1/2	1/2
Size of dome.....do.....	20 by 24	20 by 24
Diameter of stack.....do.....	16	16
Length of stack.....feet.....	25	25
Number of steel in stack.....do.....	16	16
Weight of bare boiler, on skids.....pounds..	5,300	5,800
Weight, with fixtures attached.....do.....	6,300	6,900

The following is a list of the component parts of a 25 and 35 horsepower center-crank horizontal engine and the approximate cost of replacing each part:

	25 horse- power.	35 horse- power.
Size of cylinder.....inches..	10 by 12	10 by 13
Bed frame.....	\$114.00	\$114.00
Connecting rod, complete.....	58.20	64.40
Crank shaft, complete.....	96.00	116.00
Crank pin, brass.....	13.00	14.00
Crosshead-pin, brass.....	7.50	7.50
Crosshead, complete.....	26.52	26.52
Cylinder head, plain.....	13.20	15.60
Cylinder head, with gland.....	19.80	24.00
Cylinder, complete.....	69.60	78.00
Eccentric rod.....	5.40	6.12
Eccentric rod head.....	7.68	7.68
Eccentric and strap.....	12.00	13.68
Flywheel.....	46.80	46.80
Governor pulley.....	6.12	6.60
Piston ring, each.....	2.40	2.70
Piston ring with rod fitted.....	15.72	18.24
Piston-rod gland.....	3.48	3.48
Pulley.....	13.90	13.90
Steam-chest cover.....	8.34	8.34
Valve.....	3.72	3.84
Valve stem.....	6.54	6.72
Valve-stem gland.....	4.86	4.86
Valve-stem bar.....	7.26	7.26

CARE OF BOILER.

The first duty of an engineer when he enters his boiler room in the morning is to ascertain how many gauges of water there are in the boiler. Never unbank or replenish the fires until this is done. If the water is low, cover the fires with ashes or fresh coal and close the drafts and ash-pit doors. Do not turn on the feed or tamper

with or open the safety valve. Let the steam outlets remain as they are. In really dangerous cases draw the fires.

In cases of foaming, close the throttle and keep it closed long enough to show the true level of the water. If the level is sufficiently high, feeding and blowing will suffice to correct the evil. In cases of violent foaming caused by dirty water or a change from salt to fresh water, or vice versa, check the drafts and bank the fires in addition. If leaks start in the boiler, repair them at once.

To blow off, clean the furnace and bridge of all ashes and débris. Allow the fire box or brickwork, as the case may be, to cool down for an hour or two before opening the blow-off. The pressure should not exceed 20 pounds when a boiler is blown out. Blow out at least once or twice in two weeks. In case the feed becomes muddy, blow out some every day. When surface blow cocks are used they should often be opened for a few minutes at a time. After blowing down, allow the boilers to become cool before filling up again. Cold water should never be pumped into a hot boiler; it will cause sudden contraction in the plate. In tubular boilers the handholes should often be opened and all dirt and sediment removed. When boilers are fed in front and blown off through the same pipe the mud and sediment in the rear end should be cleaned out. Raise the safety valves cautiously and frequently; otherwise they are likely to become fast in their seats and useless.

Should the gauge at any time indicate the limit of pressure allowed, see that the safety valves are blowing off. Keep the gauge cocks clear and in constant use. Glass gauges are not reliable. In preparing to get up steam after the boiler has been open or out of service, great care should be taken in making the manhole and handhole joints. The safety valve should then be blocked open, and the necessary supply of water run or pumped into the boilers. In tubular and locomotive boilers this should be until the water shows at second gauge; in vertical tubulars a higher level is advisable as a protection to the top end of the tubes. After this is done fuel may be placed on the grate, dampers opened, and fires started. If the chimney or stack is cold and does not draw properly, burn some oily waste or light chips at the base. When steam issues from the safety valve, lower the valve carefully to its seat, and note pressure and behavior of steam gauge. Under all circumstances keep the gauges, cocks, etc., clean and in good order and things generally in and about the engine and boiler in a neat condition. When a blister appears on the boiler there must be no delay in having it carefully examined and trimmed or patched. Particular care should be taken to keep the sheets and parts of the boiler exposed to the fire perfectly clean, and all tubes, flues, and connections well swept. This is particularly necessary where wood is used for fuel,

The extent of the heating surface of a boiler depends on the length and diameter of the shell and the number and size of the flues. It is customary in calculating the heating surface of the shell to consider that two-thirds of it and the entire surface of the flues is exposed to the action of the heat.

STEAM BOILER WATER.

A steam boiler needs good water as much as it needs good fuel. All water used in boilers contains more or less impurities and acid. Impurities which cause trouble include soluble salts of calcium and magnesium, bicarbonates of alkaline earths, and sulphate of lime. Water containing more than 0.005 per cent of free sulphuric or nitric acid is likely to cause serious corrosion, and more than one-tenth of 1 per cent of acid will cause scale. Hard water invariably forms scale, and comparatively soft water may also do so if the boiler is used too long without being emptied. Foaming is caused chiefly by an excess of alkaline salts, which causes the water to form suds as if soap had been placed in it.

Scale not only decreases the efficiency of the boiler but also causes deterioration: for, when it is sufficiently thick the conducting power of the boiler is reduced, and the tubes and plates become overheated and crack or burst. Again, the scale may keep the water from sections of the heated plates for some time, and then give way, causing large volumes of steam to be suddenly generated, possibly resulting in an explosion. It has been demonstrated that $\frac{1}{8}$ of an inch of scale in boilers causes a loss in heat transmission of from 10 to 12 per cent, and this loss of heat increases with the thickness of the scale. A porous scale retards the heat transmission more than a solid scale. It sometimes happens that different kinds of scale may be found in the same boiler, owing to the different temperatures of the sheet in different parts and to the circulation of the water. The scale on the tubes is also different from that on the sheets, owing to the same causes.

Methods for the purification of feed water consist of the use of feed-water heaters, scum catchers, and blow-off valves, or chemicals placed in the boiler or in the water before it reaches the boiler. Purifying chemicals placed in the boiler are soda ash, caustic soda, phosphate of soda, tannin compounds, fluoride of soda, and aluminate of soda. As a rule, the expense of purifying feed water with chemicals makes it prohibitive for small mills. The use of feed-water heaters, scum catchers, and blow-off valves, however, is strongly recommended.

To prevent the adherence of scale to the boiler shell, many substances have been used, such as potatoes, kerosene, and other remedies, organic and mineral. Of the boiler compounds found on the market none have given more general satisfaction than those which have soda

and some form of tannic acid as their base. Tannic acid has a slight action on the iron of the boiler and is reasonably efficient in preventing scale from sticking.

To prevent scale, or at least to diminish the injury it does to boilers, the feed water should be heated by live steam under boiler pressure in a separate vessel before going to the boiler. By allowing the water to settle for some time, sediment, mud, and dirt will be got rid of. Oil from the engine cylinder is particularly injurious to boilers, and, when noticed in the condensed steam, should be carefully removed.

STEAM PUMPS.

If water can not be obtained under sufficient pressure to cause it to flow into the intake by gravity, some sort of pump is necessary. Usually the pump runs by steam. If the pump runs badly, make sure the water valves and water pipes are all right before examining the steam end. When the pump is not in use in cold weather open all the cocks and drain plugs to prevent freezing. Always see that the pump has a full and steady supply of water to work on. Do not take the pump apart to see what is inside as long as it does its work well. Set a pump on a level solid foundation so as to avoid undue strain on the pipes and resulting leaky joints. Long pipes should be larger than short ones, to allow for increased friction. All pipes should be as short and straight as possible. A foot valve and strainer should be attached to the suction pipe.

Use few elbows, tees, and valves, substituting full round bends for elbows, and wyes for tees; sharp bends greatly increase the friction. Care must be taken to guard against leaks in the suction pipe, as a very small leak will supply the pump with air to its full capacity, and little or no water will be obtained. A suction air chamber made of a short nipple, a T, a piece of pipe smaller in diameter than the suction pipe and from 2 to 3 feet long, and a cap, screwed upright into the suction pipe close to the pump are always useful, and when the suction pipe is long, in high lifts, or when the pump is running at high speed, it is a positive necessity. Its use insures a steady and uniform flow of water through this suction pipe and prevents "pounding" or "water hammering."

Use good cylinder oil, and oil the steam end just before stopping the pump. Keep the stuffing boxes full of good packing, well oiled, and just tight enough to prevent leakage without excessive friction.

WATER POWER.

As a general thing, water power is not practicable for a portable mill. It may be found in one location, but not in the next. It is cheaper than steam, but the source of power is neither uniform nor

continuous; it is not as capable of control as is steam, and in most cases it gives low speed and low capacity. Descriptions of various types of water wheels will be found in the Appendix.

BELTING.

Belts transmit power from the engine to the saw. The heavier the belt the more power it transmits. Belt tighteners are required when a belt itself is not heavy or long enough to cause sufficient sag. The sag should always be on top, in order to increase the arc of contact with the pulley. Belts are made either of leather, rubber, or fabric. Leather belts are sold either single or double. The transmitting power of a single belt is only 70 per cent of that of a double belt. Rubber belts stand moisture better than leather and are cut from $\frac{1}{8}$ to $\frac{1}{4}$ inch shorter per foot than the circuit on which they run. They are run with the seam side out, while leather belts are run with the grain side in. Rubber belting is sold as 2, 4, 6, and 8 ply, the 4 ply being equal to single leather belting, the 6 ply to light double leather belting, and the 8 ply to heavy double leather belting. Small mills are usually equipped with either fabric or rubber belting.

When ordering belting of any kind it is necessary to specify (1) diameter of driving pulley, (2) its revolutions per minute, (3) diameter of driven pulley, (4) distance of pulley centers, (5) horsepower to be transmitted, and (6) width of pulley face.

Leather belting is spiked or joined either by studs or by belt cement. Next best to the cemented joint in a leather belt is that made with a rawhide or other lace. But this joint in a leather or any kind of belt must be made properly. Large lacing holes and a big bunch of lace may be almost as harmful and cause as much "jump" in the belt as a double row of studs. Where leather belting is exposed to moisture and waterproof cement is not accessible, lacing may be resorted to; but, as a general rule, all leather belts should be cemented.

In lacing a fabric belt never use a hollow punch, because it cuts the stitches and weakens the belt. Use a pointed awl. Cut the ends of the belt perfectly true with a try-square and punch or bore two rows of holes in each end. The holes in the second row should be punched directly back of the holes in the front row. The holes in both ends of the belt should also be directly opposite. No hole should be less than one-half inch from either edge or end of the belt. The holes should be spaced three-fourths inch from center to center. When an odd number of holes are to be laced, begin with the center hole; and when an even number, start with either of the two center holes. The straight stitch and hinge are the two forms of lacing in most general use. Other methods of splicing fabric and rubber belting

are also used in emergencies. Special endless belts with a diagonal splice are supplied by some manufacturers.

A belt should be capable of transmitting from 5 to 25 per cent more power than is actually needed, the excess capacity being governed by the type of drive, the smaller excess for heavy main drives, and the greatest for machine belts. Never use belts the full width of the pulley face, as a slight lack of alingment may cause part of the belt to run beyond the edge of the pulley and perhaps against a shifting finger or pulley flange. This is sure to result in loss of power and perhaps in a badly damaged belt. On the other hand, a belt too narrow necessitates high tension to transmit the required power, thus causing excessive journal friction and the early destruction of the belt.

Generally speaking, single belts, if heavy enough to carry the load, should be used on small pulleys. A single belt should never be wider than $1\frac{1}{2}$ times the diameter of the smallest pulley. Where small diameter pulleys and the load would require an unusually wide single belt, it is advisable to substitute narrower pulleys and a narrow double belt. Thin wide belts give the best service; working vertically, a thick narrow vertical belt will not grip the pulley well. Double belts of medium or heavy weight should never be used on pulleys less than 12 inches in diameter, or, even better, on pulleys less than 20 inches in diameter.

Belts too heavy for the load weave back and forth on the pulleys. This is best illustrated by a belt working under intermittent loads, which runs straight while carrying the maximum or proper load but shows a tendency to weave when the load is reduced.

The tightness with which belts are adjusted to the pulleys is of prime importance. If they are put on too tightly, there is a large unnecessary loss of power from excessive friction at the bearings, to say nothing of the overstrain and injury to the belt itself. If, on the other hand, the belt is too loose, it is likely to flop around and jump from the pulleys, particularly when a load is suddenly thrown on or off. The slacker a belt can be run up to a certain point while doing its work satisfactorily, the greater the economy. In installing belting and taking it up, it should be remembered that certain kinds of belting are affected by weather conditions, lengthening and shortening according to the amount of moisture in the air. Instances have been known where the babbitt was melted out of the boxes and even shafting pulled out of alignment as a result of belting being put on too tight.

Be sure to note carefully whether your shafting is properly in line. More belting is ruined by improperly lined shafting and pulleys than in any other way. The belts under this condition are

either kept on the pulleys by guides or rub against hangers and tear or stretch on one edge. Belts so stretched will not run straight and may slip the pulleys at any time. Remember that because your shafting was once in line it does not follow that it will stay so indefinitely. It is a very simple matter to connect two pulleys by a band in such a way that when one pulley is turned the other will go round. It is not at all a simple matter properly to proportion a drive and select the size and quality of belting which will transmit power most effectively and economically.

Shafts should not be located too close together. There should be distance enough between them to allow the belt to recover somewhat from the strain applied on the tight or working side. This distance depends entirely upon the size of the belt and pulleys, but should be sufficient to allow some slight sag to the slack side of the belt. Neither should the shafts be too far apart, for in such cases the weight of the belts draws heavily on the shafting and increases the friction load in the bearings, at the same time causing the belt to swing from side to side and sometimes to run off the pulleys. This constant swing is sometimes the cause of crooked spots in the belt, which wear out rapidly.

It is the best and most economical practice to use pulleys of large diameters, thus obtaining a high belt speed, which means a saving both in the transmission of power and in the wear and tear on the equipment. The speed of the belt being the same, pulleys of large diameters effect a slightly greater transmission of power than do those of small diameter. The speed of the shafts being the same, the advantage in favor of large pulleys over small ones is in proportion to their diameters. Wooden or leather-covered pulleys have a greater transmitting power than iron. Cold-rolled shafting is said to have 30 per cent greater strength than hot rolled. The usual diameters for shafting are from $1\frac{1}{2}$ to $3\frac{1}{2}$ inches. The proper speed is from 300 to 400 revolutions per minute, and its transmitting power is given as $\frac{D^3 \times R}{80} = \text{H. P.}$ D is diameter of shafting in inches, R revolutions per minute.

Shafts that are to be connected with each other by belts should be far enough apart to allow a gentle sag to the belt when in motion. When narrow belts are to be run over small pulleys, 15 feet is a good average, the belt having a sag of from $1\frac{1}{2}$ to 2 inches. For larger belts working on larger pulleys the distance should be from 20 to 25 feet, with a sag of from $2\frac{1}{2}$ to 4 inches. For main belts working on very large pulleys the distance should be from 25 to 30 feet, with a sag of 4 or 5 inches. If the distance between pullies is too great the belt will have an unsteady flapping motion which will tend to destroy

both belt and machinery. Regardless of the width of belt or diameter of pulley, the adhesion of the belt to the pulley is the same in all cases, provided the arc of contact and aggregate tension or weight are the same. Thus, other things being equal, a belt will slip just as readily on a pulley 4 feet in diameter as it will on a pulley 2 feet in diameter. To obtain the greatest amount of power from belts the pulleys must be covered with leather. This will allow the belts to run slack and will increase their durability by 25 per cent.

CIRCULAR SAWS.

KINDS AND COSTS.

Circular saws are either of the solid-tooth or inserted-tooth type. The advantages of inserted-tooth saws over solid-tooth saws are: The bits are cheap and can be readily set in position with the special wrench; less experience is required in dressing the saw; there is less filing and gumming; there are fewer saw repairs, which is important in a backwoods locality; and the diameter of the saw remains unchanged during its use. The disadvantages are: The saw kerf is heavy; the teeth are larger and fewer than in a solid-tooth saw; feed is comparatively slow; and the cost is higher.

For big logs and high speed a double circular saw must be used. The two saws are hung to revolve in opposite directions, so that the sawdust from the top saw will not be thrown into the lower one. The advantages of a top saw (double mill) are: It will saw bigger logs than a single mill; it will make a truer cut and saw lumber more evenly; it takes faster feed, saws more lumber, and entails less expense for saws and less repairs. The top saw may remain inactive when small logs are being cut, to avoid using up power. Inserted teeth are not used in a top-saw rig.

The approximate prices of solid-tooth and inserted-tooth saws f. o. b. Seattle, in 1916, were:

Approximate price of solid-tooth and inserted-tooth saws.

Size.	Solid tooth.	Inserted tooth.	Size.	Solid tooth.	Inserted tooth.
40-inch.....	\$23	\$44	52-inch.....	\$52	\$81
42-inch.....	26	49	54-inch.....	58	91
44-inch.....	30	53	56-inch.....	66	99
46-inch.....	36	57	58-inch.....	74	110
48-inch.....	41	62	60-inch.....	83	121
50-inch.....	47	70	62-inch.....	94	134

The amount of horsepower required for a circular saw is equal to approximately one-third of the saw's diameter in inches. In large mills each horsepower is supposed to manufacture 1,000 feet of lumber per day; in small mills only one-half that amount.

In ordering a circular saw be careful to give the following specifications in detail:

1. Diameter of the saw in inches.
2. Right or left hand mill.
3. Gauge of saw at center and at rim.
4. Number of teeth in saw.
5. Style or pattern of tooth, solid or inserted.
6. Diameter of mandrel hole, diameter of pinhole and distance, center to center of pinholes.
7. Number of revolutions of saw per minute, while in cut.
8. Greatest feed in inches per revolution and kind of feed.
9. Species of timber to be sawed.
10. Spring or swage set.
11. Horsepower available and size of belt pulley.
12. Engine speed and size of mandrel pulley.

SIZE.

The size of the saw should be governed by the size of the logs to be cut, regardless of the amount of power used. The diameter of the saw should be approximately one and a half times the diameter of the largest log to be cut. For instance, a 36-inch log needs a 54-inch saw, a 40-inch log a 60-inch saw. The width of the widest board which a single circular saw can cut equals the radius of the saw minus 3 inches; that is, a 60-inch circular saw can cut a board or plank 27 inches wide.

HANGING A SAW.

Set the saw plumb and true. Set the saw guide and adjust the guide pins clear of the teeth and just touching the plate. This should be done while the saw is in motion, care being taken that the pins do not push the saw to one side or rub hard enough to cause friction. After screwing the saw up between the collars examine the front or log side of the saw to make sure that it is flat. Never attempt to run a saw that is dishing on the log side, as it will be sure to draw toward the log and be ruined. It does not follow that because one saw works well that another will do so on the same mandrel, or that two saws will hang alike on the same mandrel.

It is absolutely necessary that the saw mandrel should be perfectly level, so that the saw will hang exactly plumb. If it is found to be rounding on the log side, cut a ring of paper about half an inch wide the size of the collar on the outside, oil it, and stick it on the face of the tight collar around the outer cage. Then cut another ring of paper the same width, making the hole the same size as the hole in the saw, put this small ring between the loose collar and the saw, and screw up the collar. If the two rings are not enough, put in more until the saw stands straight and true. If the saw hangs dishing on the log side, reverse the rings of paper; that is, put the

small rings between the saw and the fast collar and the large ring against the loose collar. If the saw heats in the center when the mandrel runs cool in the boxes, cool it off and give it a little more lead into the log. If the saw heats in the rim and not in the center, cool it off and give it a little more lead out of the log. Circular saws, revolving as they do at high speed, have a tendency to stretch on the rim, which causes them to cut out of line, dodge knots, run snaky, and become hot in the rim.

HAMMERING A SAW—BLOCKING.

To overcome rim expansion, saws are loosened in the body by hammering. This operation is called "blocking," and the effect on the saw is called tension. If after long use or through accident a saw will not run true and requires hammering, great care should be exercised in bringing it back to proper adjustment. Hammering should hardly ever be done by anyone except an expert. However, if considerable care is exercised, a person who is a fair mechanic should attain good results by practice and observation.

After taking the saw from the mandrel, stand it upright on the floor and examine it carefully on both sides with a straight edge for any inequalities such as lumps. Mark these lumps with chalk on the full or convex side, then place the saw on a block of wood and hammer lightly on the high side. Don't hammer the saw on an anvil, for that will change its tension.

If struck too heavily, the plate will be dented or the lumps knocked through to the other side. When the lumps are knocked too far it is practically impossible to get them back or to restore the equality of the plate. Lumps are sometimes round, but are usually oblong. To remove round lumps, use a round-faced hammer, which leaves an impression one-half inch in diameter. To remove oblong lumps, use a cross-faced hammer. The blows should follow the direction of the lump. Never use an ordinary carpenter's hammer; it will ruin the plate. Do not be content with putting the straight edge on once or twice and hammering a little. After a few blocks, apply the straight edge again, and continue alternatively applying the straight edge and lightly hammering until all inequalities are removed.

The saw should then be placed on an anvil (not a wooden block) and examined for tension. Raise one side so that the center of the saw just clears the anvil while the opposite side rests on the bench or wooden board, which should be 1 inch below the surface of the anvil. The body of the saw should be loose enough to drop away from a straight edge placed across the log side evenly from rim to rim. If a 36-inch straight edge is used on a 48-inch saw, you should be able to see light between the straight edge and the center. Always try the long side for this drop. If you find there is not sufficient

tension, the plate must be hammered lightly all over on both sides to within 6 or 8 inches of the center and to within 2 inches of the bottom of the sockets. The hammering must be distributed evenly with a round-faced hammer. When adjusting the tension, leave the shanks in the plate.

When hammering a saw it is necessary to know the speed at which it is to run. No saw will run properly unless hammered for the correct speed. A saw when running must be perfectly flat on the log side, although some sawyers prefer to have the edge lean slightly towards the log when the saw is standing still. This means that it is dished a very little on the log side. If, however, any such dish is allowed, it would, of course, be so slight that it could not be distinguished by the naked eye and could hardly be found with a straight edge.

A saw often becomes full on the log side. By this is meant that the rim has been forced away from the log so as to cause the dish on the board side. If there are no uneven spots in the plate other than this dish, the saw can easily be brought back by lightly hammering on the log side.

Always make sure before any hammering is done that the part of the saw which is to receive the blow is well bedded or flat on the anvil. In a perfect saw the apex or point of the V of the socket is central with the plate. If it is not central, the bit, when inserted, will lean to one side. This causes the saw to lead into, or be forced away from the log, as the case may be, and besides dishing the saw, divides the strain on the bit and shank unevenly, causing them to break.

SAW SPEED.

There is a wide difference of opinion as to proper speed of saws. The manufacturers give the maximum speed at which their saws may be operated with safety on the basis of the highest power the saws are calculated to withstand. These speeds can not be used for portable mills because of insufficient power. They are given by saw makers to show what the saw will stand and not what it is supposed to accomplish in practical work every day. While speed is power, it is easy to consume all the power in speed without doing any work. A 48-inch saw run by a 10-horsepower engine should have a speed of 300 revolutions per minute, or to give the best results, 350 revolutions per minute, and should have 24 teeth. The proper saw speed for portable mills running with 20 horsepower and under may be obtained by multiplying the horsepower by 360 and dividing the product by the circumference of the saw.

For 20 horsepower the teeth should be 5 inches apart, which will give 30 teeth to a 48-inch saw. With larger power the teeth should be closer together until they reach the limit of 3 inches apart. As

the power be increased the speed of the saw is increased correspondingly.

Saws for cutting hard wood or frozen timber are run at a higher speed than those cutting soft timber, but have more teeth.

If a saw is run at a faster or slower rate than it is hammered for, it is sure to work improperly and give trouble. A saw hammered to run at 500 r. p. m., if run at 350 to 400 r. p. m. in the cut, will be loose in the center and tight around the rim. This will cause it to run snaky or crooked in the log, heat rapidly in the center, and consume a great deal of power. On the other hand, if a saw that is hammered for slow speed, say 300 or 400 r. p. m., is run at 500 r. p. m., it will stretch too much and be tight in the center and loose and wobbly in the rim. This will cause it to heat on the rim, "flutter," run crooked in the log, and consume power uselessly. Improper speed and giving the saw too much lead into the log are the causes of nearly all the trouble experienced with saws in portable mills.

The following table, based on a saw 48 inches in diameter, may be of use in determining proper saw speed.

	Horsepower.					
	6	8	10	12	15	20
Distance between teeth from point to point.....inches.....	7	7	6	6	5	5
Teeth in saw.....number.....	22	22	24	24	30	30
Speed of saw.....revolutions per minute.....	300	300	300	350	400	450

To find the proper speed of larger or smaller saws, multiply the speed given for a 48-inch saw by 48 and divide the product by the size of the saw selected. A larger saw should have a greater number of teeth and a smaller saw a lesser number, the distance apart remaining the same. In the case of a double mill, both saws should have the same rim speed.

FILING.

Solid-tooth saws.—Do not file all the teeth from the same side, especially if each alternate tooth is bent for the set. File the teeth that are bent from you on one side and leave them on a slight bevel, with the outer corners a little the longest, and then reverse the saw and treat the other side in the same manner. Never file any saw to sharp or acute angles at the throat or roots of the teeth, but on circular lines. Any saw is likely to crack from sharp corners. The filing of angles or square corners will cancel the warranty of the saw.

Saw teeth wear narrow at the extreme points; consequently they must be kept spread (swedged) so that they will be widest at the very points. The teeth should be kept as near a uniform shape and distance apart as possible. The back or top of the tooth leads or

guides the saw in a measure, and should be filed square across. If a saw is frozen, always thaw it out before attempting to set the teeth.

The greatest wear on the saw is on the under edges of the teeth. File nearly to an edge, but not quite, leaving a short bevel of one-thirty-second of an inch wide on the underside of the point. But in no instance file to a fine point or thin wire edge. Do nearly all the filing on the underside of the teeth and see that they are well spread (swedged) at the points. File square across and have them project alike on both sides of the saw.

On crosscut saws, bevel the front of one tooth one way and the next tooth the opposite way. File rip saws square in front; use a light hammer in swedging, from three-fourths to 1 pound, holding the swedge so that the teeth will spread at the points. Swedge out wide and then dress down to the required width. Most cases of saws "crumbling" are caused by the use of too delicate a swedge. In such cases the corners of the tooth are not strong enough to stand the cutting strain.

Be sure to have a side file for jointing the teeth and keeping all the points the same length on each side of the saw.

The cost of changing solid-tooth saws into inserted-tooth saws is usually \$1.50 per tooth plus one-half the list price of a solid-tooth saw of the same size.

Inserted teeth.—It is not economical to spend much time filing inserted teeth, because new points are cheap and are quickly inserted. It should never be necessary to swedge the bits. Light filing on the underside is the only thing required to keep them sharp, because the cutting point tapers gradually and allows plenty of clearance, even though the point is worn almost entirely away. Swedging is likely to injure the shoulders and sockets, unless great care is taken in the operation. Use a light 1-pound hammer and hold the swedge so that the teeth will be spread at the point. Have a cup of oil, together with the teeth, placed conveniently near you at the back of the saw. Take the wrench and place the pins in the holes in the shank, turning the latter so that the hook projects sufficiently to receive the bit. Pick up a tooth with the other hand and dip the grooved segment into the oil, then place it in position and hold it firmly and evenly with the sides of the blade, and at the same time press the wrench downward until the shank fits into its place. The inserted teeth are exact in width and the spread uniformly good. If extra nice work is desired, try a gauge on the side of each tooth. If any are found to project a trifle too far, reduce them with a side file, being careful to preserve the same relief of the corner. No flat surface should be allowed on the side of the teeth, which must be relieved from the very point.

A properly adjusted set of inserted teeth should be used until worn out. Sharpen them as often as necessary by filing on their underside with an inserted tooth file, i. e., a mill file with one round edge. After being sharpened several times they should be relieved on the sides. Should a shank become straight or compressed, because of the saw being run on iron, so that it will not hold the bit firmly, lay it on the anvil and strike it with a hammer on the inner edge until it is expanded sufficiently to hold the bit. Do not try the experiment of bending each alternate tooth for the set. If there is any difficulty in removing an old bit for the purpose of inserting a new one, never hammer the wrench or the bit, but place a blunt cold chisel on the heel of the shank, taking care it does not touch the saw plate, and tap lightly with a hammer. This will start the bit and shank and enable you to remove them easily with the wrench. It is important that all the bits should be of equal length. In order to insure this, get a small segment or section of an old plate that can be easily held in a vise, and insert the bit that needs sharpening or swedging.

For winter sawing use a sharp bevel bit with a narrower cutting point than that used in summer. Saws over 48 inches in diameter, when made thinner than 10 gauge, $\frac{9}{64}$ scant, are not guaranteed.

KEEP YOUR SAWS IN GOOD CONDITION.

If through constant wear a saw becomes weak and limber, the sockets become out of round, and the teeth show a tendency to break or fall out, discard it at once, or send it back to the factory to be fixed up. Saws which have passed through a fire can be repaired if any life is left in the plate, but, of course, can not be made as good as new. Shoulders of inserted-tooth saws that are broken off by running against iron or stone can be welded on again, provided they are not broken off too deep in the plate. If they are broken too deep to weld, the saw can sometimes be renewed by inserting a piece of steel and boring a new socket. The tendency to discard saws or "scrap" them is very general in all mills, big and little, though in many instances, particularly in small mills, the fault lies with the sawyer and not with the saw. A little more attention to the proper care of saws would remedy this evil. If an operator leaves his machinery unhoused, as many operators do, he creates a condition which no amount of instruction can remedy.

LOG DECK.

Every mill should have a good solid log deck or skidway capable of holding from 100 to 200 logs, and built with enough pitch to permit the logs to roll down to the carriage by gravity. Logs should be piled in the yard in such a way that they can be moved to the log deck with the least possible expense and labor. This the small operator

commonly fails to do. As often as not the logs are banked in a mud hole. Sometimes 300 or 400 logs are left scattered all about the yard, so that a man and team are kept busy in getting them to the log carriage. When no team is available, the logs are often rolled by hand over slabs, rocks, and bark. The mill is stopped and all hands are called on to help.

This is surely an unnecessary waste of time and energy. Logs should never be dumped in a place from which it will cost at least half as much more to get them to the log deck as it did to load and haul them to the yard. Instead they should be piled on flat skidways in the yard, with ends touching the log road. The hauling team should then be able to keep the saw supplied directly from the woods or from the logs in stock. If the main log deck is kept full all the time the mill is running, there is little chance that logs will litter the yard.

NARROW-GAUGE LUMBER LORRY TRACK.

A narrow-gauge lorry track is almost indispensable to a small mill. The track should be at least 700 feet in length and so constructed that one man can shove a loaded lorry or car over it. The lumber piles should be built on either side of the track, to enable the lorry man to unload the lumber in front of the pile which its grade calls for. Slabs can be moved by the same means. A switch and double track just outside the mill will enable the off-bearer to load an empty car while the lorry man is unloading another in the yard and piling some of the lumber. Lorry trucks have a 26½-inch gauge and 2½-inch tread. The axles are of steel and can be used in wood frames without boxes. The size of the wheels varies from 8 to 16 inches, the weight from 110 to 262 pounds.

From a labor-saving standpoint the lorry track is one of the most important adjuncts to a portable mill outfit. It revolutionizes completely the old manner of handling lumber and does away with the unseemly clutter of slabs, lumber, and other débris around and in the mill.

When water is available a log pond and jack slip are also very desirable.

SETTING UP A PORTABLE MILL.

For foundation timbers place two pieces 10 by 10 inches by 14 feet long on either side of the saw pit (which is supposed to be 3 or 4 feet deep and underneath the husk frame) well bedded in the ground and extending out under the track stringers, taking care to have the one that is under the front end of the husk (where the sawyer stands) placed back far enough to clear the large gear wheel and so that the swinging stirrup will not strike it. One piece 6 by 6 inches by 8 feet, is saddled into the two big pieces spanning the saw pit and

underneath the far rail of the track. Never make the mistake of placing the large gear wheel between the pinion and the saw; it should be outside of the pinion. First set the husk frame and secure it to the bed timbers just where you want it. Then put the large gear wheel, with its shaft which carries the rack pin on into its proper bearings, in the central section of track timbers just where it is to work. Then lay this section of track timbers in position on the bed timbers beside the husk frame and push it forward until the large gear comes into proper mesh with the feed pinion on the end of the sliding friction shaft. The inside stringer next to the husk frame has the flat track attached to it, and is higher than the outside stringer, to provide for the difference in height of the flat and V track. The V track is placed on the outside stringer. When track stringers are not shipped with the mill, care should be taken to have the inside stringer higher, in order to bring the top of both tracks on a level. Stringers may be made of any size timber, but where the rack pinion shaft passes through the inside stringer the thickness must not be over $3\frac{1}{2}$ inches, otherwise the track pinion can not be lined with the rack on the front side of the carriage. (When the mill is a large one, No. 4 or over, this does not apply.) When stringers are not over $3\frac{1}{2}$ or $4\frac{1}{2}$ inches the crossties should be placed 18 inches apart, but if heavier stringers are used the ties can be 2 feet or more apart.

The husk and track stringers are not always on the same level on the large cross sills. In most cases the head block base must be elevated by placing a separate piece of timber under each end of the husk on top of the cross sills. Head blocks should be 1 inch above the saw collar. Do not line up under the head blocks, but raise the stringers or lower the husk frame until the blocks are in proper position.

To insure square, accurate lumber the husk frame, track, carriage, and head should be set perfectly level. The nose or front end of the head blocks should clear the saw by one-half inch. Set the track perfectly parallel with the front side of the husk frame and see that it is true and level from end to end. After setting the head blocks and set works on the carriage, pull the knees forward until they are even with the front end of the head block bases, then tighten the set-shaft coupling, and after that raise the set shaft so that the pinions will mesh deep enough in the racks under the knees to take up all lost motion. Then fasten the set-shaft bearings on the side of the head block base. These bearings are adjustable, to provide for raising and lowering the set shaft. Run the knees back and forth a few times to see if they come up even with the nose of the bases. If there is any variation it can be adjusted by the set-shaft coupling. The mandrel must be level, and the journal must fill the boxes and should be so constructed that there will be no

movement endwise when the mandrel is running. The mandrel must fill the eye of the saw, but enter freely. Always use a wrench and never a hammer on nut of arbor. The pins in the collar must have a fair bearing. Sometimes when driving them in a burr is thrown up. If not carefully filed off this tends to throw the saw over to one side.

After the mill is set up and before starting, move the carriage slowly by means of the sliding paper friction. When everything is in good order this friction can be turned easily by hand and the carriage moved in either direction. If it can not be easily moved, examine the gear and pinion to see that they do not mesh too deep or bind against the flanges; see that the rack pinions do not mesh too deeply in the rack under the carriage; also examine the set collars on the track axles to see whether they are too tight and need slight loosening. The carriage will run hard when the track is not level and straight. Give the saw from one-eighth to one-fourth inch lead in 20 feet, according to the condition of the saw and character of the lumber to be made. More or less lead is given the saw by means of set screws on either side of the main mandrel bearing. Do not try to lead the saw by pulling it over with the guide. The wood pins in a saw guide clear the bottom of the saw teeth by an inch.

A good way to give proper lead to a saw is to turn the rear head block up opposite the center of the saw, and fasten a stick or board on the head block so that the end of it is set one-eighth inch from the saw. Then run the carriage back until this stick is 20 feet from the center of the saw. Then stretch a line from the end of the stick along the face of the saw, so that it touches the saw on both edges. If it does not touch the saw on both edges, adjust the main mandrel box by the set screws on each side of it until it does. You then have one-eighth inch lead in 20 feet. This is called slewing the mandrel to regulate the lead. The same result may be obtained by sighting over the saw and fixing the saw plane for a radius of 10 feet. This may be done by placing two shafts vertically into the ground 10 feet from the saw center, behind and in front of the saw. Then a horizontal stick is fastened to a head block so as to just touch the forward staff. Then the carriage is giggered backward to the other vertical staff, where the horizontal stick must lack exactly one-eighth of an inch from touching. The belt holes or set screws in the boxes of most mandrels are slotted, and it is only necessary to loosen the set screws and move the boxes one way or the other by a few light blows of a hammer in order to get the proper lead.

OPERATING THE MILL.

First see that everything has been set up according to directions and all nuts are tight. Then with kerosene or benzine carefully clean the turned surfaces of the friction disk and the sliding friction

shaft, taking care that no oil or grease or any foreign substances get on the paper frictions. Nothing should ever be put on these; simply keep them clean and dry, and covered so that the greasy sawdust will not get into them and cut them out. If the frictions should become wet, a little fine sawdust will dry them nicely. All bearings must be kept clean and supplied with an abundance of good machine oil. Where grease cups are used, they must be filled with a good grade of grease and kept covered so that dirt and grit will not work into them. It is a good plan to go over all of these at regular intervals and clean out the oil holes.

Start the mill up slowly, see that the bearings are not too tight, and also that they do not run hot. Do not try to cut up a log the very first thing. Run the mill empty for a while and watch every working part to see that there is no heating and that nothing needs adjustment. Be a little slack on the frictions until you learn just how to work them nicely. By carelessness or crowding the pressure on the frictions before everything is working nice and easy, you may grind a flat place on the sliding paper friction and destroy its usefulness. When everything is properly set up and correctly adjusted a very slight pressure of the hand on the feed lever is all that is necessary to run the carriage when sawing.

Do not fasten the stirrup in any way at the bottom, but leave it free to swing back and forth as the feed lever is pressed to or from the disk. The upper end of the stirrup must be fastened to the iron lug at the bottom of the yoke of the sliding box with a cap screw. It must also fit up in the socket of the sliding box, so that it will move the box forward and bring the sliding friction up against the disk when the feed lever is pressed forward.

SAWING.

For your first sawing pick out moderate-sized logs. Do not try to get full capacity out of your mill for the first day or two. See that the log is dogged firmly to the knees, saw slowly and get the "hang" of your mill, and let the working parts all get in good running order. Use an extra quantity of oil until everything is working easily and smoothly. By studying the set works on the carriage, you will soon learn to cut any desired thickness of lumber.

A working knowledge of how to run a saw can be easily acquired. Of course, it is the better way, if possible, to take lessons from some one who has already had experience of this kind. If, however, no one is available, start very slowly until you know just what feed you can give the various-sized logs. To insure that the logs will be cut to best advantage, the amateur sawmill operator should take a pair of dividers or a piece of string and a pencil and lay out several

circles representing sizes of different logs, and then draw in the ends of the boards or stock in the way you wish to cut them. You will soon learn the best way to turn and handle logs so as to get the most desirable and best-sized pieces out of each log. Keep your mill clean and take away the sawdust and do not let everything become covered up with oil and dirt. Keep all nuts tightened up and look your mill over every day before starting. You will thus save many shutdowns.

As opposed to this plan, many sawyers cut their logs up "alive" without turning the log at all, edging the boards afterwards with the circular saw. This system may be dismissed as the very "limit" in wasteful milling. Another plan, which is followed by quite a number of operators, is to slab off the boards on four sides of the log, leaving the wane on each board, and cutting up the squared portion into planks or boards. This method of sawing is made to act as a grading medium for the lumber; and, accordingly, we find such operators selling their lumber as square edge, sheeting, and waney edge, with square-edge lumber topping the price list and the others in order. In reality, the waney edge, if run through an edger, is the best lumber cut from the outside of the log, although by this method classed as lowest in price and grade. However, this is a little better than the "saw-'em-alive" system, for it enables the operator to secure a higher price for his product, although mixing his grades unintentionally. The better and more successful class of operators keep close supervision on the sawyer to see that he gets the maximum amount of good lumber out of each log, grade their lumber more or less carefully, and pile it in the yard according to grade and dimensions. They are generally equipped with a light planer and edger, and some few have a floorer. A few of these operators occasionally buy the better quality of lumber from the less thrifty millmen of the "saw-'em-alive" class, grade, edge, and surface it, and make more profit than the man who logged and milled it in the first instance.

The greatest defect in connection with a portable mill seems to lie in the irregular size of the lumber produced, arising from the inability of the sawyer to get the proper "lead" in sawing. Next to this is lack of sufficient power in boiler and engine. The effective horsepower available in most cases is far below what the mill owner supposes. He may have an engine of 25 or 30 indicated horsepower, while the effective power for working purposes may be only 10, owing to the excessive friction, badly lined machinery, poor belting, and leaking cylinders. Under such conditions the only thing for the millman to do is to employ a competent mechanic and have his mill overhauled and put in proper shape. The operator who does not keep his mill in good working order had better get rid of it at once.

PILING LUMBER.

Every pile of lumber should rest on three strong horizontal ground sills. The front sill should be higher than the middle and back sills. The front of the pile should be given an overhanging "batter" to protect it from the rain. The usual pitch is 1 foot to 10. The tiers of boards are kept apart by three or four well-seasoned crosspieces called "sticks" sawed about 1 inch square and placed directly over one another in the tiers. The usual width of a pile is from 6 to 10 feet, and the distance between piles ought to be 3 feet. Each pile must contain equal lengths, as "overlaps" are sure to get spoiled. A sufficient air chamber should be left in the center of the pile so that the stock may dry rapidly. When fresh-sawed lumber is allowed to touch, discoloration of the portions touching is sure to ensue. Each pile should have a roof 12 inches high in front and 6 inches high in the back, projecting on all sides. In order to prevent end cracks, the sticking should be placed exactly at the ends and slightly projecting over them. Inch boards and planks should be handled carefully when being piled or loaded on wagons. If slammed down violently, as is the custom, end checks are likely to develop into cracks or splits which spoil the grade of the piece.

A 2-acre yard or piling space is necessary for a small mill carrying 50,000 board feet in stock. Select good level ground for your lumber yard and see that the lumber is neatly piled according to size and grade. You will get more for your lumber if you can show it to a customer in this condition than where it is all dumped in a heap. Remember that the mill run is ordinarily sold at a loss to the millman, as the buyer grades it according to the lowest quality in the whole pile and not according to the high grades which, in properly piled stock, would be sold separately and at higher prices.

FIRE PROTECTION.

There is little use in going to the expense of putting up a mill if it is allowed to burn down. Fire is an ever-present danger. For writing a policy on the ordinary small mill fire insurance companies charge a premium equivalent to 20 per cent of the mill's value, which makes the expense of insurance prohibitive in most cases. It is up to the owner, then, to provide fire protection. This can be done by installing liquid chemical extinguishers or dry chemical extinguishers or water hose that can be attached to the boiler. Liquid chemical extinguishers may freeze in winter, and dry chemical extinguishers are expensive. The most practical equipment for a portable mill is water hose, and in the following table is given the capacity of such hose at various pressures:

Capacity of water hose at various pressures (size of nozzle, 1 inch).

	Pressure of nozzle.			
	40 pounds.	60 pounds.	80 pounds.	100 pounds.
Pressure at pump with 100 feet of 2½-inch rubber hose, pounds.....	48	73	97	121
Gallons per minute.....	155	189	219	245
Horizontal distance thrown, feet.....	109	142	168	186
Vertical distance, feet.....	79	108	131	148

LOGGING.

SAW CREW AND EQUIPMENT.

For a mill cutting 10,000 feet (from 9 to 11 logs per thousand), two pony gangs are necessary. If the sawyers do not understand felling and how to get straight logs and good lengths out of the tree after it is felled, it may be necessary to have an experienced undercutter with the two gangs. One of the crew should be able to file and fit a saw properly. Incidentally, the saw should be a good one, so that the filer does not waste time trying to sharpen it, or the sawyers lose 5 or 10 minutes in every cut. The same applies to axes. An axe is intended to chop, not to bruise timber, and must be kept sharp if it is to be used effectively. It should be ground on a grindstone, not rubbed with a file. It would be interesting to know how many men working round a small mill understand how to grind an ax properly. The knowledge of making ax handles, oxbows, and yokes is a lost art, yet when a man is working 20 or 30 miles away from a hardware store and there are no ax handles in camp, this knowledge would come in handy.

A saw gang of two men, equipped with the proper tools and working in timber which will run from 8 to 10 logs per 1,000 feet, will ordinarily cut between 5,000 and 6,000 feet per day, the logs varying in length from 12 to 16 feet. The average wage for this class of work in 1916 was approximately \$3 per day, board not included. If the average cut is 5,000 feet per day, the cost per 1,000 for sawing would be \$1.20. On the other hand, take two equally good sawyers and equip them with a rusty worn-out saw, poor axes, and no wedges, and the best they can cut will be around 3,000 feet per day. At the same rate of wages this timber will cost the operator \$2 per 1,000 for bucking alone. The latter crew loses the price of a new crosscut saw every seven working days, or the price of a new ax every day. Lack of good cant hooks, swamp hooks, logging chains, etc., cuts further into the profit margin.

Each saw gang should be provided with a pair of good steel wedges (preferably forged crucible tool steel) and a maul to drive them. The usual practice is for the sawyer to stop and whittle out a wooden

wedge when he needs it. In doing this a gang of sawyers loses more time each day than is represented by the cost of a set of good steel wedges. If not equipped with a maul, a sawyer will spoil a dollar ax in five minutes trying to drive steel wedges with it. Tying the wedges together with baling wire when not in use will prevent them from being lost. Each gang should have a flat bottle, easily carried in the hip pocket, to hold kerosene with which to spray the saw occasionally.

CROSSCUT SAWS.

Ordinarily a 6-foot saw is best adapted to the size of timber in the inter-mountain country. In some stands, however, a longer saw is necessary. The back of the saw is always somewhat thinner than the gauge of the teeth, and usually about two gauges heavier on the ends, which makes it stiffer and prevents "buckling" when the sawyer pushes a trifle on the back stroke.

There are two kinds of teeth, viz., the cutting teeth and rakers. Only the points of the cutters actually cut into the fiber; the rakers are meant to plane off the fiber severed by the cutting teeth and to drag the sawdust out of the cut. A curved saw will cut faster and with less exertion than a straight saw.

A filer's outfit consists of a jointer, a raker tooth gauge, files, a raker swage, a set block, and a light hammer. In fitting a saw the teeth should first be jointed or made uniform in length. To do this place a 9-inch file in the jointer and, by means of the large screw, spring it to suit the curve of the saw and pass it lightly over the points of the teeth until it touches the shortest tooth. Then place the tooth gauge over the cleaner drag teeth and file them down to the gauge, afterwards filing them squarely across to a point as desired.

If the saw requires setting, place the setting block on a log that has been leveled to receive it, then place the saw upon the setting block so that the point of the tooth to be set projects over the apex of the beveled surface fully one-fourth of an inch. Then give two or three strokes with a light hammer on the side of the tooth over the apex fully one-fourth inch from the point which will usually give the required set. Then move the tooth forward over the bevel or channelling block and strike it a sharp blow directly over the point. This will make a slight depression below the point of the tooth, which serves to keep the cutting edges flush, giving them greater cutting power and relieving the pressure on the back of the tooth. Regulate the set by gauging each tooth with the tooth gauge. Take the gauge in the left hand and place it against the side of the saw. The point on the short end indicates the least set, and the point on the long end indicates a little more set. Experienced saw filers say that setting should never go lower than half the length of the tooth,

should never exceed twice the gauge of the tooth, and that more set is needed in long saws and for softwoods than for short saws and hardwoods.

The side file should be used to remove any feather edge or burr left in filing and to even up the set perfectly. This can be done while the saw is in the vise or filing clamp. Place an 8-inch mill bastard file in the recess on the side file and tighten the screws holding the file. Be particular that the saw is held firmly in the clamp. Pass the center of the file lightly against the teeth until the burr is removed and the set evened up. Care should be taken not to use the side file more than is necessary to remove the feather edge and even up the set. The wrench may be used to lessen the set if necessary, but should never be used to set the teeth. This should be done only with a hammer upon the setting block or on any hard and slightly beveled surface. Notice carefully the manner in which the saw is filed when new, and file as nearly as possible along the same lines.

To secure the best results, the saw should be sharpened after being set. If it is desired merely to swage the point of the rakers, this may be done with a light blow of the hammer on the extreme point of the raker teeth. A raker gauge, the flange of which rests on the points of the cutting teeth, is useful for inexperienced saw filers. The filer can reduce the projecting points with the file until stopped by the edge of the gauge. In this manner tooth after tooth can be rapidly and correctly reduced to an even length by any unskilled operator.

A saw now on the market has the teeth in groups of three, the center one a cutting tooth and the ones on either side rakers. The cutting teeth are set, but the rakers are not. The saw can be used for any kind of timber, the teeth varying in size according to the work they are to do. The raker teeth are beveled to form a sharp point and have cutting edges, thus forming a combined raker and cutting tooth. This is the distinctive feature of the saw.

In ripping, the bottom of the kerf is cut sideways. This causes the saw to rip faster and easier than the old-style rip saw, which works chisel fashion and has to cut the wood almost square across the grain. The set which is given the cutting teeth assists the rakers very materially by cutting the kerf a little wider than the raker teeth and by cutting the sides of the kerf perfectly smooth. This causes the saw to run freely and easily. Ripping is done by cutting, instead of tearing, as is the case with the old-style rip saw.

In crosscutting, the teeth cut in four different lines in the kerf. In this way the fibers are cut in small, short pieces and are much easier to break out than if they extended clear across the kerf. As all teeth are of the same length they loosen the sawdust clear to the bottom of the kerf, thus removing much friction that occurs where a square raker tooth is used. This style of tooth works equally well

in ripping, miter, or crosscutting, and in all kinds of soft and hard wood, as well as where knots occur and the grain is tangled in many different directions. That the saw will cut faster and run easier either way than any other saw that is filed for one purpose is claimed by the makers. No gauge is required to cut the raker teeth down to the proper length, nor does it materially interfere with the proper working of the saw if raker or cutting teeth are filed shorter than the others here and there.

In filing this saw, joint down the points of the teeth with a flat file until the file touches every tooth. Set the cutting teeth (the middle teeth in every group) a good ways back, making a gradual bend, then pass a flat file along the sides of the teeth to even the set. File all the raker and cutting teeth almost to a point; then file to form a chisel point. Pass a flat file along the sides of the teeth to remove the featheredge. Keep the saw in a leaning position, as it enables you to file a full bevel. The more bevel you give the teeth the faster the saw will cut. Carefully notice the shape of the teeth in a new saw and file to conform with them as nearly as possible.

The file should be laid between the teeth, with its flat side on the bevel of the tooth you are filing, but without touching the point of the next tooth. Each tooth is filed separately. The teeth, when new, are cut deeper than is required for the angle of the tooth, so that the bevel is full only a little ways down from the point. After a few filings, however, the bevel will be full clear down to the base of the tooth. In this way every filing will gum all teeth except the big gullet, and that should be filed frequently to afford plenty of room for cleaning out the sawdust. This can be done with the edge of a flat file, or with a round one, if you prefer a round gullet. Do not file the gullet wider than it is in a new saw.

NOTCHING AND FELLING.

The proper method of felling, bucking, skidding, and loading logs is one of the principal subjects upon which the average mill operator needs information. When not properly handled, it is likely to be one of the costliest items in his business.

Run a cut in the butt of the tree to be felled as deep as the size of the tree calls for and at right angles to the direction in which the tree is supposed to fall. Take the axe and chip out a notch above the cut or below it, leaving a clear notch in the butt. When the bark is rough at the base of the tree, chop a girdle round in the line of the saw cut. But before doing this, select the best ground on which to fall the tree, to prevent breaking or pinching when the tree is being made into logs. If the tree to be felled leans heavily in one direction, it is the better plan to notch a little to one side or the other to which the tree leans, and after starting the cut in the opposite side

of the tree (notch) "saw round" or cut the corners, leaving a couple of inches of the fiber between the saw cut and the notch uncut on one corner. In this way the strain which will be exerted when the tree is falling will pull the body of the tree in the direction you want it to fall. "Sawing round" prevents a leaning tree from splitting on the stump and possibly breaking the saw.

In felling very tall straight timber with a heavy crown it is sometimes difficult to ascertain in which direction the tree leans the heaviest until the saw is half way in the cut, when the saw becomes fast and requires heavy wedging to loosen it. In wedging such trees, great care should be taken to prevent them from coming back over the cut and injuring the men. Thick wooden wedges are used in extreme cases of this kind. Men felling timber should always yell "timber" before the tree starts to fall, and when it starts, should remove the saw and stand clear.

The tree should never be completely severed from the stump. Ordinarily a tree, when falling, will break off 2 or 3 inches of the fiber between the saw cut and the notch. A heavy notch which leaves a long stub on the butt log should be avoided.

Sawyers should endeavor to fall the timber as favorably as possible for skidding purposes, and in a way to prevent the cuts from pinching the saw. A little care along those lines will perceptibly affect the volume of cut. Keep count of the number of logs each gang cuts per day.

If a tree lodges in another when falling, fall the one it is lodged against at once, or, if you are an expert in judging the direction of falling timber, fall another one against the one lodged so as to bring down the latter. Never continue working around a lodged tree. It is likely to hit you when you are not expecting it.

After a tree is down, the limbs should be cut off close to the bole and thrown out of the way. The next step is to measure off each log by placing the measuring stick (8 feet long) flat on the bole and clipping a piece of bark off at the end of the first 8 feet, then moving the stick forward to the exact length of the log to be cut and making a plain notch in the bark for 2 or 3 inches over the exact length, to allow for trimming and broomage on the ends. Walk alongside the tree, and not on it, when measuring the logs.

All logs should be straight. If a sweep occurs in a tree, cut in the sweep. If a cut pinches, cut a double length log and get the teamster to pull it out to where it can be sawed without "pinching." If there is a break, cut up to the break and start your next log on the other side of it. If a crotch is in the tree, cut out the crotch, but don't waste any lumber in doing it. If a felled tree balances on a knoll or on another tree, prop the light end. If part of the bole is limby and part is smooth, have as much of the smooth portion as possible

in one or two logs and the rough knotty portions in different cuts. If a tree is punky or dozy or has dry knots or blind punk, measure off the logs so as to confine the defective part, as much as possible, to one log length. Sever each log completely from the one next to it. Cut up all down timber and skid it before felling any green timber on top of it. Do not leave a "chip" at the bottom of each cut—it annoys the skidder. Do not saw anything but the log. If the ground is higher than the bottom of the log, "saw short" or dig a channel for the saw; look out for rocks. Do not allow your saw to "run"—make a square cut every time.

Where there is an undercutter on the job—and there should not be one unless he understands his business—it is a good plan to have him notch a number of trees ahead for the sawyers to fell. This enables the sawyers to work to better advantage with the skidders. Before bucking up any of the down timber, the undercutter can trim the trees ahead of the saw gang, who will then have no brush to retard their work, while the skidding teamster can figure ahead on his skid roads. Brush disposal should follow skidding.

A logger should cut his log lengths with a strict regard to the current prices for lumber of different lengths. Then, if he grades his lumber, he will not sell what should be 2-inch No. 1 shop, 12 inches wide, 18 and 20 feet long, as No. 3 common.

PREPARING SPECIAL PRODUCTS.

Mine props, telegraph, telephone, or power poles should be trimmed and peeled, piled carefully according to lengths, and air dried before shipment. The successful marketing of such special products depends largely on how they are prepared. If a mine operator gives an order for a carload or two of 7-foot mine props and gets an assortment of green props of irregular lengths with the ends chopped or "chewed" off, the bark on, and snags all over the bole, be assured that if he accepts them at all it will be at a reduced price and that he will look to some other source for material in the future. Careless preparation has in more than one instance prevented the utilization of large quantities of timber which, if properly handled, would have been entirely acceptable to the mining operators. When a mine operator has to "fit" each prop after receiving it, that is, trim the knots off, peel it, and square the ends to the proper length, he is doing work which you should have done, and he knows it. Again, if a mine operator places an order for green lodgepole pine, do not try to pass off dead timber of the same species or ship a mixed carload of alpine fir, white fir, aspen, and lodgepole. You may work off one carload, but that will be all.

When such material has to be shipped by rail, freight charges become an important factor in favor of the local man. Yet the foreign

shipper who prepares his mine timbers properly can, on a 400-mile rail haul, create and hold a market for the same species of mine prop material which the local operator can not sell at all, although his product is 300 or more miles closer to the consuming center. The sole reason is that the local man does not prepare his material properly. Tell the mine operator just what species of timber you have for sale and ship it to him properly made up and you will hold his trade.

THE MAIN LOGGING ROAD.

A logger should never forget that it is cheaper and more economical to haul a load of logs a quarter of a mile to his mill on a downhill road or on the level than it is to haul a similar load a rod uphill. Run the main road through the stand to be cut, if the ground is level, or below the timber if the stand is on a side hill. Keep your cutting area compact, and when you make a skid road, take out all the timber tributary to it before you move to the next one.

If you have to haul up a hill, double up; do not figure on loads that one team can handle over a hill. If the road is too steep, use a block and line. Do not waste time in trying to force your single team to haul a load which a four-horse team can hardly get away with. If the ground is rough and rocky, use dynamite and build a good main road and keep it in good order. Breakage and wear and tear on equipment and horses over a bad road will buy a lot of powder and keep a road in fine shape.

One thousand feet of logs weigh approximately $4\frac{1}{2}$ tons. It would take a good team to haul such a load over a paved street. Why try to haul it over rocks, ruts, and logs when logging in the hills with a pair of cayuses? A logger should remember that the value of the time lost and the injury to teams and equipment while struggling to pull off impossible stunts in logging is always a prolific source of loss. If iced or even snow roads were possible, it might be different; but a dirt road must be well built.

If the timber is large, use a gin pole and crotch line in loading; use bunk chains or corner binds in holding the first tier of logs on the truck or sled. A couple of logs on top of the binding chain will hold them taut. A spring pole is dangerous to use and not a safe bind on a load of logs. Have your toggle bind and grabs on the unloading side.

It sometimes happens that part of the timber is relatively close to the mill and part farther away and not so accessible, and the character of the road such as to prevent the hauling of a maximum load every trip. In this case it will be found economical to skid up the "close" timber along the main road and "top off" the long-haul loads to their full capacity on their way to the mill.

SKIDDING.

Skid or dray roads are not supposed to receive as much attention in construction as main logging roads. Nevertheless, they should be kept reasonably clear and should be laid out with considerable care. On steep hillsides it is sometimes feasible to build benth roads along the face of the hill. The logs are skidded to the nearest bench and then rolled by hand to the next bench, and so on down to the base of the hill, where the trucks can handle them to the landing. In some cases where the power (oxen or horses) is available and the distance to the mill is not over half a mile logging "from the stump" can be done to advantage.

Use a dray or go-devil to skid the logs out to the main road. Skidding logs by chain, except on a downhill haul, or on level, smooth ground, is waste of time. A team can haul three logs on a dray over rough ground with less effort than it takes to haul one log by tongs or a chain.

When a tree is cut into logs in the woods, the skidding teamster should place his dray alongside the end log with a short skid resting on the dray, set his swamp hook low down on the far side of the log, hitch his whiffletrees to the swamp-hook chain, start up his team, and roll the log onto the bunk of the dray. If the log is a big one, it should be peeled on the side which drags on the ground. If your team can haul more than one log, fasten the first log on the dray and move up to the next and repeat the same operation. If the tree has fallen in a position difficult to load easily, hitch on the block and line and boost the log out to where it can be handled. Do not make your team pull a log on the chains or tongs out of a pothole or from between two rocks or stumps simply for the satisfaction of seeing them do it. Get the log out in the easiest and quickest way possible and spare the team and rigging.

When loading logs on the skidway, place the ends which will come on the front of the load even. This can be done very easily when filling the skidway, but not so easily with the skidway full. "Rossing," or peeling the bark off logs, particularly large ones, will make skidding easier and prevent insect attack. "Snipping" the forward end is also resorted to, but a log so large and heavy that the front end digs into the ground when being hauled on a chain or tongs should be loaded on a dray.

Logs on a travois or dray should be balanced on the bunk of the dray in such a manner that approximately two-thirds of the weight of the load is behind the bunk. Logs will haul easier when the heaviest end drags on the ground. They should be so balanced that if the runners should strike on a rock, the dray will partially lift

and slide over the obstruction. If the load rests wholly on the bunk and runners, the team will be unable to lift the load.

In addition to the main binding chain, on the end of which there is usually a round hook, a skidding teamster should always be provided with a grab or fit hook with which to keep his load snug and to take up slack when necessary.

Snags and stumps should be removed or cut low along a skid road. Windfalls and loose rocks should be thrown out of the road, and chuck holes filled up. Never try to haul or skid logs over a swamp or bog unless it is frozen hard enough to carry teams; build a corduroy road. If water is available, the skidding teams should be fed in the timber. Build a brush shelter equipped with feed boxes and keep a few days' supply of hay and grain stored there. Remove the harness while the horses are feeding. Never, if it can be avoided, throw grain on the ground for teams to eat. Have fly nets for the horses in warm weather and keep the horses shod.

Skidding equipment consists of good harness, whiffletrees and trace chains, logging chain, cold shuts, tongs, swamp hook, cant hooks, ax, "Sampson," travois or dray, skids, block and line. A jackknife dray, with a 3-foot bunk spiked and fitted with bunk chains, is preferred. This dray is so constructed that if it strikes any obstruction it will "jackknife," or partially fold. There should be spike skids for decking on the skidways when teams are not available. Both smooth and spiked skids should be shod with iron on one end to prevent slipping. When teams are not available and the logs are small (10 per 1,000 feet), two men can load ("spike") logs onto a truck or "deck"; but when large logs are being handled a gin pole and loading line (parbuckle) is necessary. If the men are inexperienced in the use of cant hooks, as is usually the case in small operations, a crotch loading line is preferable, because one end of the log can not slide ahead when rolling up the skid, as it is likely to do in a single line, particularly if the log is larger at one end than at the other. Several small logs can be "sent up" in a crotch line at one trip, but not so easily in a single line.

SKIDWAYS.

A skidway should be centrally located and the approach so graded or so gradual as to avoid an uphill haul. The end of the skids should be blocked or preferably bridged apart, so that the team will have firm footing when crossing the skids. The front end or head blocks should, if possible, be high enough to make it possible, when the skids rest on them, to roll on the first tier of logs by hand. The skids should have a slight slope toward the front. The ground alongside the skidway should be cleared of brush, so that the longest log will not catch on the ends. It is not worth while to build a skid-

way at all if logs can not be handled from it faster and with less effort than they can be loaded among the brush on the dray road. The purpose of a skidway is to expedite the work. A poor skidway will retard it.

Chaining or tonging logs onto a skidway, except on a close haul, is not recommended. A tonged or chained log, unless turned on the chain or tongs before it strikes the skids, will tear up the approach and make hard hauling. A dray is much better, for besides hauling more logs to a trip it is not so hard on the approach to the skids.

A skidway should be 4 feet wide or wider, if the logs are double length, and long enough to hold at least one day's haul without decking. The skids should be tolerably straight, of equal height, and free from knots. If the skids are unusually long they should be blocked up in the center to prevent them from sagging or breaking. If possible, it is a good plan to embed the hind end of the skids in the ground. If the logs are small and light, a light-built skidway will answer the purpose; if heavy logs are to be loaded, make it solid.

I have seen four men with two teams struggle for two hours to load an 800 board-foot log on a truck from smooth skids and fail, while all the time the teams stood idle. Yet with an improvised parbuckle (a rope spliced to a logging chain) the same log was loaded with the aid of a team in five minutes. In this instance the haul to the mill was a quarter of a mile, and it took four men and two teams one-half a day to land that log on the mill yard, and cost the operator \$7, or at the rate of \$9 per 1,000 for loading and hauling alone. The log was the butt cut of a five-log tree and not entirely severed from the next log. Instead of skidding the five logs to the main road where there was a good skidway chance, and where that log and another one could have been loaded by hand upon the truck, the operator attempted to load the log at the stump. The heaviest part of the haul was from the stump to the main road. Owing to the position of the logs, only one could be loaded on the truck, even though the four horses might have handled more than one. The men had no cant hook or swamp hook with which to roll the log over and no loading line or parbuckle by which to load it. Handspikes and an old peevy and a piece of a logging chain were the only equipment available. The operator, on being asked how he expected to load logs with such equipment, replied: "Oh, all our logs are not as big as this one; the boys usually breast them up." If this man had had a dray or go-devil, a swamp hook, cant hook, and loading line, with a skidway close by on the main road, his teamster could have loaded this log on the dray, hauled it to the skidway with the other logs in the tree, and loaded two logs on the truck very easily. The hauling team could have made six trips a day instead of two, and the loading and hauling would have cost \$1.80 per 1,000 instead of \$9.

In practice it invariably happens that a small-mill operator who watches this part of the work carefully makes a success of his business. The average operator usually lets the job by contract to inexperienced men at twice what it could be, or ought to be, done for, in order to be rid of it. At a conservative estimate the logging to small mills costs \$1.50 to \$2.50 per 1,000 more than it ought to cost. This unnecessary expense swallows up the greater portion of the profits that can be made in operating a small mill. Misdirected energy in this line means a loss to the operator which can not be made up.

CHUTES.

When the country to be logged is split up into narrow canyons or gulches and is not too steep, chute logging can be carried on with more or less success. When the chute has a heavy grade and the logs attain a high velocity at the landing, the loss in breakage is too heavy to justify this method of handling timber. In fact, chute logging is most successful where the grade is so light that horses are necessary to keep the logs moving. Twenty or more logs dogged in a string propelled by horsepower can be taken over a chute rather cheaply.

If the distance to "chute" exceeds a mile, beats should be laid off in one-fourth mile sections, with a man and team to keep each one clear. In small operations, of course, one man and team or one horse and man are enough. In addition, a team or single horse is needed to keep clear the point where the logs are being delivered to the chute.

When the grade is heavy, soft steel goosenecks are used to check the speed of the logs, and the delivery end of the chute is elevated in order to insure that the logs will fall flat instead of striking "end on." Logs handled in this way are generally split in the end and badly bruised up, even when they are landed in water.

Chutes are usually built of 20-foot logs laid two abreast and hewed trough-shaped by cutting away the inner faces. The logs are drift bolted to bed pieces that are sunk firmly in the ground, 12 to 14 feet apart. The average size of chute timbers is 14 inches at the top. The average cost of chute construction is \$3 per rod.

A chute in which logs run by gravity is called a running chute, and one with which horses are used, a trailing chute. Sometimes logs will run on one part of a chute and are trailed on other parts. Heavy logs will run on lighter grades than small, light, short logs. Trailing chutes should be greased, or, if the weather permits, iced.

The main trouble about chutes is that very often they are not constructed properly, particularly chutes built around sharp curves. A running chute should never be built with a bad curve. It costs too much to keep in repair, and logs will be constantly jumping. In

small jobs when the ground is adapted to chutes and the operator has some experience in chute building, their use is strongly recommended. The cost will not be more than that of a good road, which few operators build. Moreover, the cost of trying to get his logs to his mill over a bad road will be avoided. Small operators seldom cut logs over 18 feet in length, and these can be taken around a pretty sharp curve on a trailing chute. The operator must, however, build a good chute, or else he can not use it.

Big logs should be peeled or rossed for chuting. The average cost of trailing logs in a chute varies from 50 cents to \$1.50 per 1,000. Well-built chutes will, if kept in repair, last from 7 to 10 years. If not needed for that period the timbers can be taken up, and after all the spikes are removed can be cut into lumber. The usual grades for long logs are—

	Per cent.
Dry chute.....	15 to 20
Ice chutes.....	4 to 8
Water chutes.....	3 to 6

For short logs, ties, mine props, and field posts the grades are—

	Per cent.
Dry chute.....	25 to 35
Iced chutes.....	8 to 12
Water chutes.....	5 to 8

Hardwoods are better than conifers for chute construction. The grade of inlet must be steep, and the outlet in running chutes should be into a pond of water of sufficient depth to keep the logs from striking bottom.

LOADING LOGS.

It is important to load in the right way, for every time a log is moved unnecessarily there is a cut in the operator's profit.

Dig a hole for the gin pole deep enough to prevent the pole from sliding out but loose enough to admit of the pole being pushed back a few inches in order to clear the logs when the load is being hauled away. Make the gin pole fast to the sway bars of the truck or sled with a short chain and grab. See that the truck or sled is in proper line with the front end of the logs to be loaded. Set up the skids with the ironed tips resting on the bunks or sway bars and (as this is addressed to portable millmen) use a crotch line with light swamp hooks on either end. Make each dog fast in the end of the bunk or in the side of the sway bar. After it is passed round the log hitch the loading line on the whiffletree or equalizer, start the team up slowly, and see that the log is coming fairly on to the bunks and not faster on one end than the other. Be careful that one end does not miss the bunk and fall between them on the reach or hounds.

A crotch line is recommended for portable mill loggers because it is much safer for inexperienced loaders, although slower than a single line. After a little practice in the use of cant hooks, however, a green man will soon learn to "cut" a log which is inclined to go endwise on the skids (cannon). In such cases the loader should step in front of the lower end of the log and catch it smartly with his hook, at the same time pulling so that the end will slide forward on the skids. If he happens to be on the side which is moving too fast, he should catch the log smartly from behind and by a sudden pull hold that end while the other or slower end slides forward. This operation requires quickness and dexterity in the use of the hook. A green hand is likely to catch his hook too deep in the timber, with the result that he gets a severe jolt and his cant-hook stock is broken.

A loader should never stand behind a log going up in the chain. When a log is safely on the load he should have the next log rolled down to the skids, help to pull back the chain far enough to encircle the log and to reach the load, and hand the swamp hook to the loader, who makes it fast to a log already on the load, usually the log in front of the one beside which he intends the log in the chain to lie. The top loader grabs the log with his cant hook, after fastening his swamp hook in the log to prevent it rolling over when the team pulls on the chain, yells to the teamster to go ahead, and keeps clear of the log as it rolls into its place. A good top loader figures ahead on where he intends to place his logs in order that the load will balance. If one side of a sled load of logs is heavier than the other, the load usually becomes "bunk bound" and will not steer properly, and naturally, if a truck is not loaded properly, it will tip over.

Corner binds and binding chains should be used in hauling logs on a truck or sled. Binding or spring poles are not reliable, besides being dangerous if they happen to slip. Good stout block brakes are a requisite on steep hills. These should be secure enough to enable a logger to stop "dead" on the steepest hill—rough locking the hind wheels with stout chains if necessary. The neck yoke, breast straps, and hame straps should be carefully looked over every day and kept in proper shape.

The cross haul for the team should be brushed out and the ground leveled off so that the team can haul to good advantage and turn around easily. Sometimes when a block is used on the gin pole the loading team pulls parallel to the load and along the road. If this can be done, the crosshaul can be dispensed with.

When a load is taken off the front of a skidway the remaining logs should be rolled down to the front, in order to make room for more logs on the end. It does not pay to deck (pile up) logs in a

small operation. Medium-sized logs can be decked a couple of tiers high in spiked skids quite easily, thereby saving the expense of a decking team and teamster.

If you are hauling on a snow or ice road, keep the space in front of the skidways on which the sled stands free from bark and chips. Figure on loading the heaviest logs on the bottom of the tier. If the sawyers leave any knots on the logs, trim them off close to the bole and see that the binding chains or toggles are grabbed on the unloading side. If the sawyers have left a "chip" on the bottom of the cut, set the "Samson" (which should be higher than the log) on the near side, drop the swamp hook over the far side of the log, and fasten in the dog. Make the swamp-hook chain or logging chain fast with a half hitch around the top of the "Samson," and hitch the team to the chain. One pull from the team usually breaks the chip or turns the log over so that the teamster can reach it with his ax. If the teamster is not equipped with a swamp hook and does not understand how to use a "Samson," he can take a "roll" on the log with his log chain, with the draft down low on the side of the log opposite his team, and if the log is not too heavy and the chip too large, can lift the log far enough with his team to enable him to cut the chip with his ax and roll the log on to the dray.

The jackknife dray has a roller in front set on gudgeons in the nose of the runners. A stout bunk armed with spikes connects the runners. If the dray strikes any obstruction it will "jackknife" or partially fold, hence the name.

SCALING.

There are many rules for the measurement of saw logs. None of them, however, is mathematically exact, simply because a saw log is not a mathematical figure. Also, the unit of sawed lumber is 144 square inches, or a piece of board 12 inches square and 1 inch thick. Any rule purporting to give the actual amount of board feet which a log of a given diameter will saw out is, therefore, only an approximation.

The Decimal C rule is the one adopted by the Forest Service for scaling Government timber. This rule is made by dropping the unit figures of the Scribner rule and accepting the nearest tens as correct values. The contents of logs as given by the Scribner rule were found by drawing diagrams outlining the smaller end sections of logs and computing the board feet in the boards that could be sawed from them.

The Doyle rule, which is extensively used, is based on the following formula: Deduct 4 inches from the diameter of the log, square one-fourth of the remainder, and multiply by the length of the log in feet. This gives the approximate contents in board feet. Another

rule of more ancient origin, which gives the same results, is to deduct 4 inches from the diameter of the log as an allowance for sawdust and slabs, then multiply the remainder by half itself, and the product by the length of the log in feet, and divide by 8. The quotient will be the number of square feet contained in the log. Still another giving the same contents is, deduct 4 inches and square the remainder, adding to or deducting for the aliquot parts of a longer or shorter log.

The Doyle rule gives less values in board feet for 16-foot logs up to 28 inches in diameter than the Scribner or the Decimal C rule, and above that diameter gives greater values. Between 22 and 28 inches in diameter, however, there is only a slight difference between the two rules. The 14 single logs ranging from 8 to 21 inches in diameter scale by the latter rule 12 per cent more than with the Doyle, though logs scaled by the Decimal C rule overrun the log scale by an average of 10 per cent when manufactured into lumber.

The requirements of the Forest Service call for the measurement of sound material in the log irrespective of grade. Allowance is made for bad defects, such as rot, shake, check, cat face, crooks, wormholes, etc., or a serious combination of one or more such defects in one log. In timber of high commercial value, logs are classed as cull that have two-thirds of the gross scale defective; in the case of inferior species, such as fir, lodgepole, and balsam, one-half of the gross scale.

It very often happens that timber or logs containing only one-third of the gross scale in merchantable lumber will not pay the cost of handling unless the lumber obtained is high grade. In such cases the scaler should possess a knowledge of grades and be qualified to differentiate between a log that pays for merchandizing and one that does not.

The only true analysis of what a defective log will scale is found by seeing it opened up in the mill. A scaler's ability to make proper allowance for defect hinges on his experience in this particular respect. Defects such as large loose or unsound knots, an occasional knot hole, a great deal of pitch and pockets, some red rot and bad season checks, large wormholes, and any amount of blue stain, unless combined in one log, affect merely the quality or grade and not the quantity of merchantable lumber produced from the log. They are therefore not recognized as justifying a scaler in discounting the gross scale of a log.

The fact of logs overrunning the log scale—that is, cutting more board feet than is shown on the Decimal C rule—should not be considered by a scaler in making allowance for defect. This matter of overrun is, in Forest Service sales, taken into account when ap-

praising the timber and establishing the stumpage price, and is not relevant to scaling.

The following grading rules for western yellow pine logs are suggested by the Forest Service for use in eastern Oregon and Washington, and could be profitably used by portable mill operators in any section of the country:

No. 1 clear logs shall be 22 inches or over in diameter inside the bark at the small end and not less than 10 feet long. They shall be reasonably straight grained, practically surface clear, and with not less than 25 per cent of their scaled contents capable of being cut into C select and better.

No. 2 shop logs shall be 18 inches and over in diameter inside the bark at the small end, not less than 8 feet long, and with not less than 30 per cent of their scaled contents capable of being cut into No. 2 shop or better.

No. 3 rough logs shall be 6 inches and over in diameter inside the bark at the small end and not less than 8 feet long, and having defects which unfit them for classification in the two above grades.

C select grade means lumber 4 inches wide or wider. Knots, blue stain, some pitch or season checks are admissible. A 4-inch or 6-inch piece would show light traces of pitch or season checks. Heavier indications of pitch and season checks are permissible in wider boards, but should not be scattered all over the board. Medium blue stain, covering one-third of the face, if not in combination with other defects, is admissible.

No. 2 shop means a grade of lumber valued for cutting purposes only. The grade of No. 2 door cuttings will admit of one defect in one piece. This may be a small sound knot not to exceed five-eighths of an inch in diameter, or a light-blue stain which does not extend over more than one-half the surface of the piece on one side, or, in the absence of all other defects, one small season check not to exceed 8 inches in length and showing on one side of the piece only. Each plank of No. 2 shop should contain either one of the following: At least 25 per cent of No. 1 door cuttings or not less than $33\frac{1}{3}$ per cent of No. 1 and No. 2 door cuttings combined.

Rough logs of the grade lower than Nos. 1 and 2 consist of lumber the general appearance of which is coarse, admitting many defects in inch lumber and all defects common to dimension lumber that do not materially impair the strength of the piece.

LOGGING OUTFIT.

Following is a logging outfit for class A mills and its cost:

4 teams and harness, at \$400.....	\$1, 600
Saws, axes, wedges, cant hooks, chains, and blacksmith outfit.....	150
2 logging trucks.....	250
2 lumber wagons.....	200
Camp cook outfit.....	100
Sleeping camp.....	50
Lubricating oil and kerosene.....	20
Total.....	2, 370

The following equipment would be suitable for a class B mill:

5 teams and harness, at \$400-----	\$2, 000
Saws, axes, wedges, cant hooks, chains, and blacksmith outfit-----	150
2 logging trucks-----	250
2 lumber wagons-----	200
2 drays-----	10
Cook camp outfit-----	150
Sleeping camp-----	70
Lubricating oil and kerosene-----	20
Total-----	2, 850

Below is given an outfit of blacksmith tools for small loggers and others doing their own work:

Coal and borax.
 60-pound anvil, with hardies.
 Leg vice, 35-pound, opens 4 inches.
 Lever forge, 60-pound.
 Upright drill.
 Round shank drill.
 6 taps and 3 set dies.
 Cold chisel.
 Assorted punches.
 Tongs, pincers, and rasps.
 Farrier's knife.
 Shoeing and turning hammer.
 Hoof parer, horseshoes and nails, calks, and sling for shoeing unruly horses.

The following constitute logging accessories:

Logging trucks, Montana, \$130 each.
 Lindsay self-loading skidder, 2 wheels, 24 inches diameter; 5-inch tire, \$30; 8-inch tire, \$35; 10-inch tire, \$40.
 Four-wheel logging trucks: Weight, 1,200 pounds, capacity, 4,000 pounds;¹ weight, 1,800 pounds, capacity, 10,000 pounds.
 Large-size cant hooks, 5½-foot stock.
 Swamp hooks, steel.
 Skidding tongs, opening 24 to 30 inches.
 Emery or carborundum wheels, 10 inches diameter and 1 inch thick.
 Runners, with McLaren's casting, finished and ironed, set of four.
 Bolster plates, four to a sled.
 Gudgeon pins.
 King bolt.
 Pole caps.
 Tote sleds.
 Logging sleds (no bunks), complete. (Shipping weight, 2,400 pounds.)
 Big wheels, 7 to 10 feet high.
 Lumber buggies, capacity, 2,000 pounds; weight, 300 pounds.
 Dump carts, 2-horse, weight, 1,900 pounds; 1-horse, weight, 1,300 pounds.
 Two-horse wagons with box, weight, 1,350 pounds.
 Boot calks for driving boots.
 Square shovels, D handles, 38 inches over all.

¹ This rig includes whiffletrees, eveners, stay chains, neck yoke, or tongue chains. Brake, \$10 extra. Two-wheel carts with straight or arched axle.

Round shovels, **D** handles, 38 inches over all.
 Shovels, long-handled, square pointed, 61 inches over all; round pointed, 61 inches over all.
 Spades, **D**-handles, 39 inches over all.
 Snow shovels.
 Earth augers for holes 5 to 8 inches diameter; 8 to 14 inches diameter.
 Posthole tamping bars.
 Hayforks, 4 tines.
 Manure forks.
 Manure **D**-handled forks.
 Railroad and grading plows.
 Wheel scrapers.
 Slushers.
 Slushers, double bottom.
 Wheelbarrows, tubular steel frames.
 Wheelbarrows, wood.
 Dynamite, 40 per cent (20 cents per pound in 25 to 50 pound boxes).
 Caps, per 1,000, No. 3.
 Safety fuse, 50 feet in coil, 2 coils in a package, per 1,000 feet, single tape.
 Blasting powder, 25-pound sheet-iron kegs, black F.
 Blasting machine, size 13 by 9 by 6 $\frac{3}{4}$ inches, weight 35 pounds, capacity 1 to 30 holes.

Following is a list of tools and stores:

Pickarooms or hookarooms: Axe-handle shape; straight handle.
 Pike poles with straight pikes, 14 to 16 feet.
 Pike poles with hook and straight pike.
 Straight pike only.
 Pike with hook.
 Adz handles.
 Spike maul handles.
 Riveting and farrier's handles.
 Round chain hooks.
 Corner bind or fid hooks, flat.
 Half round fid hooks.
 Boom chains made to order.
 Log jammer blocks.
 Loading blocks.
 Skidding tongs.
 Rollway breaking hooks.
 Loading hooks.
 Swamp hooks, steel.
 Cant hooks, iron clasp.
 Cant hooks, steel clasp.
 Peavies, malleable socket.
 Peavies, steel socket.
 Cant hook and peavy handles.
 Cant hook and peavy hooks.
 Top loader, heavy steel.
 Peavy sockets.
 Cant-hook clasps.
 Toe rings, iron.
 Toe rings, steel.
 Hook and peavy bolts.

Ax handles, single bitted.

Ax handles, double bitted.

Axes, single bitted.

Axes, double bitted.

Broadax handles, Michigan.

Pick and mattock handles.

Maul handles.

Broadaxes.

Driving batteaux.

Paddles.

Anchors.

Road rutters.

Badger road rutter.

Snowplow and road rutter (Eau Claire).

Logging sled stock: Pole, rock elm; white oak. Finished and iron pole,
and roll, elm; roll, oak.

APPENDIX.

WATER.

One gallon of water weighs $8\frac{1}{3}$ pounds and contains 231 cubic inches. One cubic foot of water contains $7\frac{1}{2}$ gallons, 1,728 cubic inches, and weighs $62\frac{1}{2}$ pounds. One cubic inch of water evaporated under atmospheric pressure is converted into approximately one cubic foot of steam. The height of a column of fresh water equal to 1 pound pressure per square inch is 2.31 feet. In usual computation this is taken at 2 feet.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by 0.434. Approximately every foot elevation is equal to one-half pound pressure per square inch, allowing for friction.

Pressure of water for each foot in height.

Feet in height.	Pounds per square inch.	Feet in height.	Pounds per square inch.	Feet in height.	Pounds per square inch.
1.....	0.43	15.....	6.49	50.....	21.65
2.....	.86	20.....	8.66	70.....	30.32
5.....	2.16	25.....	10.82	80.....	34.65
10.....	4.33	40.....	17.32	100.....	43.31

To find the velocity in feet per minute necessary to discharge a given volume of water in a given time, multiply the number of cubic feet of water by 144 and divide the product by the area of the pipe in inches. Doubling the diameter of a pipe increases its capacity four times. A miner's inch of water is approximately equal to a supply of 12 gallons a minute.

Measurement of an open stream by velocity and cross section.—Measure the depth of the water at from 6 to 12 points across the stream at equal distances between. Add all the depths in feet and inches together and divide by the number of measurements. This will give the average depth, which when multiplied by the width will give the area of the cross section.

The velocity of the stream can be found by laying off 100 feet along the bank and throwing a float into the middle, noting the time taken in passing over 100 feet. Do this a number of times and take the average. Then divide this distance by the time, and it will be the velocity at the surface. As the top of the stream flows faster

than the bottom or sides the average velocity being approximately 83 per cent of the surface velocity at the middle, it is recommended to measure a distance of 120 feet for the float to run and reckon it as 100.

Multiply the area of the cross section by the velocity of the stream in feet per minute, and the result will be within 12 per cent of the discharge in cubic feet per minute.

To compute the capacity of pumping engines.—Multiply the area of the water piston in inches by the distance it travels in inches in a given time. Deduct 3 per cent for slip and rod displacement. The product divided by 231 gives the number of gallons in the time named.

Barometric pressure varies at different altitudes with an equivalent variation in the vertical suction lift of the pumps.

An "atmosphere," $14\frac{7}{10}$ pounds, at 62° F. is equal to a column of mercury 29.9 inches high, or a column of water $33\frac{9}{10}$ feet high.

Water at high temperature can not be raised any considerable distance by suction, as the vapor discharged from the water follows the receding piston of the pump and resists the entrance of the water; consequently, to pump hot water always have the supply above the pump so that it will be supplied from a head.

STEAM.

Under the ordinary atmospheric pressure of 14.7 pounds per square inch, water boils at 212° F., passing off as steam, the temperature at which it boils varying with the variation in the pressure. Steam rising from water at its boiling point (212° F.) has a pressure equal to the atmosphere, viz, 14.7 pounds to the square inch at sea level. To evaporate 1 cubic foot of water requires the consumption of $7\frac{1}{2}$ pounds ordinary coal, or about 1 pound of coal or $2\frac{1}{2}$ pounds wood to 1 gallon of water. Steam is transparent, colorless, dry, and invisible except when partly condensed, when the mist makes it visible. Dry steam does not contain any free moisture; wet steam contains free moisture in the form of spray or mist and has the same temperature as dry saturated steam of the same pressure. Saturated steam is steam in its normal state, that is, steam whose temperature is that due its pressure, by which is meant steam at the same temperature as that of the water from which it was generated and upon which it rests. Superheated steam is steam at a temperature above that due its pressure after leaving the liquid from which it is generated.

One cubic inch of water evaporated into steam at 212° F. becomes 1,645 cubic inches, that is, nearly 1 cubic foot. Water introduced into superheated steam will be vaporized until the steam becomes saturated and its temperature becomes that due its pressure. Cold

water or water at a lower temperature than that of the steam, when introduced into saturated steam, will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due its pressure. The speed of steam for designers of steam piping is about a mile and one-half per minute and sometimes much more.

There is a saving of approximately 1 per cent in fuel burned for every 11° that feed water is warmed before being run into the boiler. If sufficient exhaust steam is available and cold water at 70° is raised to 210° the saving in fuel will approximate 12 per cent.

FUEL.

One cord of air-dried hickory or hard maple weighs about 4,500 pounds and is equal as fuel to 2,000 pounds coal.

One cord of air-dried white oak weighs about 3,850 pounds and is equal to 1,715 pounds coal.

One cord of air-dried red oak or black oak weighs 3,250 pounds and is equal to 1,450 pounds coal.

One cord air-dried poplar, chestnut, or elm weighs 2,350 pounds and is equal to 1,050 pounds coal.

One cord of air-dried yellow, white, or lodgepole pine weighs 2,000 pounds and is equal to 625 pounds coal.

From the foregoing data it is safe to assume that 2½ pounds dry wood is equal to 1 pound average-quality soft coal, and that the fuel value of the same weight of different woods is very nearly the same. That is, 1 pound of hickory is worth no more for fuel than a pound of pine, assuming both to be dry. It is important that the wood be dry, as each 10 per cent of water or moisture will detract 12 per cent from its value as fuel. This fact should be noted by small mill operators who use green slabs for fuel and sell the dry ones. In one case observed by the writer the dry slabs were sold in the mill yard at 1 cent each and the green ones used to fire with. During the afternoon the mill stopped four times, averaging 15 minutes each time, in order to get sufficient steam to run the saw, and then the sawyer had to "back up" the carriage several times to enable the saw to gather sufficient speed to cut a foot or two farther into the log.

Evaporative power of 1 pound of various fuels at atmospheric pressure (14.7 pounds).—1 pound good coal will evaporate 10 pounds water; 1 pound crude petroleum will evaporate 16 pounds water; 1 pound natural gas (25 cubic feet) will evaporate 20 pounds water.

WATER WHEELS.

The horse power of falling water is expressed in the formula $\frac{V \times H \times 62.5}{33,000}$, which means that the volume of discharge in cubic feet

per minute multiplied by the height of fall in feet, multiplied by the weight of a cubic foot of water, and divided by 33,000, gives the horse power per minute.

Amount of water required to develop a given horsepower with a given available effective head.¹

Effective head.	Flow of water per minute.			
	10 H. P.	20 H. P.	30 H. P.	40 H. P.
	<i>Cubic feet.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>	<i>Cubic feet.</i>
50 feet.....	125	250	375	500
60 feet.....	104	208	312	416
70 feet.....	88	177	266	355
80 feet.....	77	155	232	311
90 feet.....	70	140	210	280
100 feet.....	63	125	186	248

¹ Horsepower based in 85 per cent efficiency of the wheel.

Water wheels are built either overshot, breast, undershot, or turbines.

Overshot wheel.—The effective power is 60 to 75 per cent of possible power. The proper velocity of the circumference is 5 feet per second and is equal to approximately one-half the velocity of the water. The water velocity must be greater than the rim of the wheel. In falls of from 20 to 40 feet in height the overshot wheel is more effective than a turbine. The buckets should have a capacity three times as large as the volume of water actually carried, should have holes in the bottom in order to allow the escape of air, and have a depth of from 12 to 14 inches and be 12 inches apart at least from centers. The speed necessary to run a sawmill with this power is obtained by countershaft or gears.

Breast wheel.—The water acts by weight and impact, dropping vertically into the buckets. The efficiency varies from 45 to 65 per cent of possible power and works best in falls from 8 to 16 feet having a discharge from 20 to 80 cubic feet per second. The speed of the wheel should be such as to fill the buckets one-half their capacity each revolution. Other forms of breast wheel are called "high breast," "low breast," and "flutter" wheels. The old form of water wheel had radial buckets, but the modern idea is in favor of curved buckets which give a higher efficiency.

Undershot wheel.—The undershot or current wheels have a low efficiency and are usually anchored in rapid streams in such a position as to be safe during floods or high water. The size of the wheel varies. It usually has 12 blades, each one of which is submerged as it passes directly under the axle. All of those wheels have become practically obsolete in this country.

The Pelton turbine is a type of axial flow impulse turbine in which a small jet issues from a nozzle and strikes on a series of cups of

the shape of two hemispheres joined together at the center by a straight thin rib. By this means the jet is split and returned without serious shock. The speed of the rim should be one-half of the jet velocity to give the highest efficiency. The water works by impact and pressure and not by weight, as in vertical wheels, and greater speed is directly transmitted, which makes a turbine wheel better adapted for sawmill purposes than a vertical one.

The advantage of water-power mills is less operating expense. The disadvantages are: Water-power mills are not portable; the source of power not uniform or continuous; not as capable of control as steam; and in the majority of cases results in low speed and low capacity.

ENGINE FRICTION BRAKE.

The engine friction brake is an instrument for measuring the power which an engine can give off for external use. It is usually applied to a flywheel and will give results if the belting is properly adjusted and the shafting in line. The object of a flywheel is to compensate for the irregular turning movements, and to prevent the consequent variation of speed from exceeding certain predetermined limits. The energy stored in a flywheel varies as the square of the velocity and directly as the weight. In the case of solid cast iron of good quality the velocity of the rim should not exceed 80 feet per second and in built-up wheels 50 feet.

STANDARD HORSEPOWER.

Standard horsepower is 33,000 foot-pounds. A foot-pound is 1 pound lifted 1 foot per minute or any equivalent amount of force, such as one-half pound lifted 2 feet or 12 pounds lifted 1 inch per minute. The horsepower of an engine may be determined by the following formula: $H. P. = \frac{2 \times PLAN}{33,000}$. When P=mean effective pressure, L=length of the stroke in feet, A=average net area of piston, and N=number of revolutions per minute. To calculate horsepower, multiply the area of the piston in square inches by the speed of the piston in feet per minute and divide the product by 33,000. The result is the horsepower value of 1 pound mean effective pressure, which, if multiplied by the whole mean effective pressure, will give the indicated horsepower. The net effective horsepower is the indicated horsepower less the friction of the engine.

GEARS.

The word "diameter" when applied to gears is always understood to mean the pitch diameters. Diameter pitch of the gear is the number of teeth to each inch of its pitch diameter. If a gear has 40 teeth

and the pitch diameter is 4 inches, the diametral pitch is 10, or, properly speaking, the gear is 10 diametral pitch. Circular pitch is the distance from the center of one tooth to the center of the next tooth measured along the pitch circle. If this distance is one-half inch, the gear is said to be one-half circular pitch.

CALCULATING THE SPEED OF SAWS, PULLEYS, AND DRUMS.

EXAMPLES.

1. A 30-inch pulley, making 180 revolutions per minute, drives a countershaft with a 12-inch pulley. What is the speed of the smaller pulley? $180 \times 30 \div 12 = 450$ r. p. m.

2. A countershaft is to make 450 r. p. m., driven by a 30-inch pulley making 180 r. p. m. What will be the diameter of the countershaft pulley? $180 \times 30 \div 450 = 12$ -inch pulley.

3. What will be the diameter of a pulley making 180 r. p. m. to drive a 12-inch pulley 450 r. p. m.? $450 \times 12 \div 180 = 30$ -inch pulley.

SAW GAUGE.

Stubs's standard English gauge is in general use by saw manufacturers in this country.

No. of wire gauge.	Fractional equivalents.	Decimal equivalent.
		<i>Inch.</i>
No. 1.....	$\frac{1}{16}$ inch scant.....	.300
No. 2.....	$\frac{1}{8}$ inch full.....	.284
No. 3.....	$\frac{3}{16}$ inch scant.....	.259
No. 4.....	$\frac{1}{4}$ inch full.....	.238
No. 5.....	$\frac{5}{16}$ inch full.....	.220
No. 6.....	$\frac{3}{8}$ inch scant.....	.203
No. 7.....	$\frac{1}{2}$ inch full.....	.180
No. 8.....	$\frac{5}{8}$ inch scant.....	.165
No. 9.....	$\frac{3}{4}$ inch full.....	.148
No. 10.....	$\frac{7}{8}$ inch scant.....	.134
No. 11.....	1 inch scant.....	.120
No. 12.....	$\frac{1}{4}$ inch scant.....	.109
No. 13.....	$\frac{3}{8}$ inch full.....	.095
No. 14.....	$\frac{1}{2}$ inch full.....	.083
No. 15.....	$\frac{3}{4}$ scant.....	.072
No. 16.....	$\frac{1}{2}$ inch full.....	.065
No. 17.....	$\frac{1}{4}$ inch scant.....	.058
No. 18.....	$\frac{1}{8}$ inch full.....	.049

MILL-MACHINERY TERMS.

Back (of a saw tooth)—The upper or convex part of a saw tooth. The lower or concave portion is called the face.

Bit—A tooth used in an inserted tooth saw. The knives used on the cutter heads of surfacing machines to cut a tongue and groove.

Board mill—One that makes a specialty of 1-inch and 2-inch lumber as compared to a timber mill which cuts lumber of greater thickness.

Bumper—A device placed at each end of the carriage run to absorb the shock. It is usually a piston fitted with a cylinder which contains live steam or air, buffer.

Cant flipper—Two or more horizontal bars placed in a line of live rolls; the outer ends are fastened to a common shaft attached to the piston of a steam cylinder and the near ends are pivoted to a firm support. On elevating the outer ends, cants and boards are transferred to a temporary storage point behind the gang resaw or edger.

Carriage—A frame on which are mounted the head blocks, set work and other mechanism for holding the log while it is being sawed and also for advancing the log toward the saw line after a cut has been made. The carriage frame is mounted on trucks which travel on tracks. The carriage is moved by steam, feed cable, or rack and pinion.

Carriage dog—A steel tooth, several of which are attached to a carriage knee and operated by a lever. Their object is to hold the log firmly on the carriage.

Carriage feed—The power used to drive the carriage back and forth. It may consist of a rack and pinion, a cable device, or a large cylinder and piston. In large mills the steam cylinder is used for short carriages and the cable for long ones. In portable mills the rack and pinion or cable feed is used.

Carriage receder—A device on the under side of a carriage which automatically shunts the carriage frame on its axles about $\frac{1}{2}$ inch away from the saw line. The carriage receder is used only in band mills; its use prevents the log from hitting the band saw.

Chip breaker—A roller, or bar in front of cutter knives on a planing machine to prevent splinters from being torn from the face of the board as it is being surfaced.

Circular gang mill—A machine usually used to cut 1-inch flooring strips from 4-inch and 6-inch cants.

Circular saw—One having cutting teeth on the circumference of the plate.

Dished saw—Circular saws may assume a shape like that of a dish. The concave side is spoken of as the dished side.

Double-cutting band saw—Has teeth on both edges and cuts on both forward and backward run.

Double mill—A mill having two head saws.

Edger—A frame supporting an arbor on which are mounted several saws, feed rolls, press rolls, and power transmission gear. It is used to square-edge lumber and also to rip it.

Edge stacker—A machine which piles lumber on edge on dry-kiln trucks.

Feed rolls—Live rollers with a smooth, corrugated, or rough surface which holds the lumber and pushes it into an edger, resaw, planer, etc.

Felloe—One of the segments of the rim of a wheel between the spokes and the tire.

Floorer—A planer and matcher combined which makes flooring.

Friction nigger—A long lever armed with teeth used to turn logs on a carriage.

Gang edger—An edger that has fixed saws.

Gang mill—A machine with a heavy frame supporting a sash which carries straight saw blades. The sash runs in upright slides and is driven from below.

Gang saw—One from 6 to 10 inches wide and 4 feet in length with teeth on one edge, suspended in the sash of the gang and cutting on the down strokes.

Syn.—Gate saw.

Gauge—The thickness of a saw blade.

Head block—The part of a carriage which holds the log and upon which it rests.

Each head block consists of a base, a knee, a taper set, and a rack and pinion gear.

High track or dollyway—An elevated tramway which runs from the sawmill to the yard.

Hog—A refuse grinder.

- Hookaroon, pickaroon—A curved pike fitted to handle, used in pulling ties or lumber into place.
- Horizontal band saw—A band saw which runs horizontally.
- Husk—The frame supporting the arbor and other parts of a circular saw.
- Inserted tooth circular saw—One in which removable shanks and bits are inserted in the sockets on the rim.
- Jump saw—One that can be raised or lowered in a vertical line.
- Jack slip—The trough up which the bull chain hauls the logs.
- Knee—The part of a carriage holding the dogs and also the levers operating both the dogs and the taper set.
- Log deck—The platform in a sawmill upon which logs are stored preparatory to placing them on the carriage.
- Log lift—Cable slings, spaced several feet apart—employed to lift logs from water.
- Loose—A saw is said to be loose when the surface falls away too much from the straight edge.
- Lumber buggy—Dolly lumber truck.
- Lumber jack—A tripod armed with a blunt spike on top, used as a fulcrum to pass the lumber up to the lumber piler.
- Matcher—A surfacing machine used in a planing mill for finishing lumber of average width and thickness. Syn.—Joiner.
- Out of round—A circular saw is said to be out of round when it is not a perfect circle.
- Overhead trimmer—One which has the saws hung above the table.
- Pond saw—A power-driven drag saw used to cut logs in a mill pond.
- Press roll—A live roll which holds the lumber against the feed roll when passing through a machine.
- Resaw—A circular or band mill used to resaw boards, cants, plank, timbers. Syn.—Pony band mill slab saw.
- Rift gang mill—A machine for cutting edge-grained flooring strips from a cant. It consists of a number of small circulars set on the arbor of an edger.
- Rock saw—A circular saw or a planer head which removes a wide kerf on the upper surface of the log in front of the cut of the head saw.
- Rotary veneer machine—A machine that cuts or peels a thin endless sheet of wood from a round log.
- Sash saw—An upright band of steel toothed on one edge stretched in a sash or frame and used singly usually in a water-power mill of limited capacity.
- Saw arbor—The shaft and bearings on which a circular saw is mounted.
- Saw guide—A device for steadying a circular or band saw.
- Screw rollers—Rollers with a coarse thread which throw the board or slab to one side as the piece passes over it.
- Set beam—A shaft on a sawmill carriage connected with the set works bearing pinions, one of which meshes into a rack in each headblock and moves the knees back or forth as desired.
- Setting block—A small steel block on which the tooth of a crosscut saw is placed and then struck with a hammer to give it the proper set.
- Set works—The mechanism on a sawmill carriage by means of which the setter advances the knees and the log toward the saw line after a piece has been cut from the log.
- Set-works scale—A dial on a sawmill carriage which shows the distance between the saw line and the face of the knee.
- Shank—Device for locking inserted teeth into the sockets of a circular saw.
- Shotgun feed—Steam feed.

- Single band—A band saw with one cutting edge; a double band is toothed on both edges.
- Single mill—A mill with one head saw.
- Sizer—A machine for surfacing timber.
- Slasher—Several circulars mounted on the same line from 16 to 24 inches apart for cutting up slabs, edging, etc.
- Solid-tooth circular saw—One in which the teeth are cut into the rim of the saw.
- Spring set—When one tooth in a saw is sprung slightly to the right and the next one to the left alternately; crosscut and narrow band saws are spring set.
- Standard band mill—One having a 50,000 daily capacity from a single band.
- Steam feed (or shotgun feed)—A long cylinder with a piston which is fixed to the rear end of the carriage and propels it back and forth.
- Steam niggers—A heavy-toothed lever worked by steam cylinders which is used to turn logs on the carriage.
- Sticker—Small pieces of boards placed between courses in a lumber pile or a machine used in a sash, door, and blind factory for shaping doors, sash rails, sash bars, and muntins.
- Swage—A tool used to spread the points of the teeth of a saw.
- Swage set—Hammering the points of the teeth to a width greater than the thickness of the saw. Head saws are usually spring set and some rip saws also.
- Taper lever—A lever attached to the knee of a carriage headblock which throws either knee out of alignment when cutting churn-butted logs.
- Tension—To make a band or circular looser in the middle than on the cutting edge, by hammering.
- Throat—The rounded cavity below the points in which sawdust gathers and is carried from the cut.
- Tire—Is that part of a band-saw blade 1 inch or more back from the throats which has not been stretched to conform with the segment to which the rest of the blade is tensioned. This leaves the saw tighter at the tire than it is in the middle. The width of the tire varies with the width of the saw and the amount of tension carried.
- To gig a carriage—Running the carriage back after a board is cut from the log.
- To gum a saw—To grind out the throats of a saw.
- To hammer a saw—To round it with a hammer in order to adjust the tension.
- To hang a saw—To place a saw in position ready for operation.
- To jack logs—To pull logs from the pond into the mill on an endless spiked chain. Syn.—Bull chain, jacker, log haul.
- Top saw—The upper of two circular saws on a head saw, both being on the same husk.
- Whip saw—A saw operated by two men used to cut logs into lumber. Syn.—Pit saw.

LUMBER TERMS.

- Backing board—The last board in the log left on the carriage.
- Barn boards—Boards used for barn siding. The cracks between the boards are covered with battens.
- Base—Interior trim which is fastened to the walls of a room at the floor line.
- Battens—Narrow lumber used to cover cracks between siding boards.
- Bevel cribbing—Boards beveled on both edges, used to cover the sides of a corner.
- Bevel siding—Lap siding, siding weather board.

Block setter—One who operates the set works on a sawmill carriage.

Blued lumber—Lumber, the sapwood of which has been stained by fungi.

Box boards—Lumber of a specific quality from which boxes are manufactured.

Box shooks—Pieces of lumber cut to size for boxes but not assembled.

Break down—To cut a log into cants or of a size which can be sawed on the main saw.

Bull head—A term used by sawmill filer to describe the action of a saw when it leads in or out of a cut.

Cant—A log which has been slabbed on one or more sides.

Casehardened lumber—Material, the exterior of which is dry, while the interior remains moist. The result of quick drying in an overheated kiln.

Ceiling—Lumber usually finished on one side only and used for wainscoting, ceiling rooms, etc.

Chimney—An opening left from top to bottom in a lumber pile to admit air and hasten drying.

Chipped grain—A defect in lumber caused by the grain of the wood being torn out in patches by the action of the planer knives.

Clapboard—Siding 4 to 6 inches wide and 4 to 20 feet long tapering to a thin edge on one side.

Case knot—One surrounded wholly or partially by pitch or bark.

Coarse-grain lumber—Material with wide annual rings.

Comb grained—The best quality of quarter-sawed lumber, the growth rings of which are nearly at right angles to the face of the board.

Common boards—Applied to four grades of lumber of a quality inferior to finish. The widths run from 4 to 12 inches.

Common dimensions—Applied to 2-inch stock ranging from 4 to 12 inches wide and 3-inch stock from 6 to 12 inches wide.

Custom sawing—The sawing of lumber under contract prices per 1,000 board feet.

Carriage setter—Rides on the front end of the carriage and sets the dogs which hold the log in place.

Drop siding—A pattern of lumber used to cover the exterior sides of buildings.

Syn.—Cove siding, German siding, patent siding, rustic.

Face side—That side of a board which shows the best quality.

Featheredge—When a board is found thinner on one edge than it is on the other it is said to have a featheredge. Term also used to describe an over-sharpened cutting edge.

Feed—The length of lumber cut at one revolution of the saw, expressed in inches.

Fencing—A grade of rough inch lumber 4 to 6 inches wide.

Fine grain—Lumber having the annual rings close together.

Finish lumber—The higher grade of lumber used for interior finish in buildings.

Five-ply veneer—Made up of five pieces of veneer glued one to the other, also called laminated wood.

Flitch—A thick piece of lumber with wane on the edge.

Furring—A narrow strip of inch lumber which is nailed to rafters and joints as a backing for laths.

Jointed flooring—A flooring strip which instead of being tongued and grooved has the sides cut on a bevel edge. Syn.—Lap siding.

Joist—A dimension timber used to support the floor of a building.

Knocked down—A machine or article taken apart in order to facilitate shipping. Abbreviated as K. D.

Large knot—One that is over 1½ inches diameter.

- Load**—In foreign markets 1,680 pounds weight of lumber or 50 cubic feet cargo space.
- Lumber tally**—The scale of the log after it is cut into lumber.
- Mill run**—All of the lumber without regard to grade which has a shipping value.
- Moulding**—The narrow strips of lumber moulded in various patterns used in interior finish.
- Odd lengths**—Lumber trimmed to odd feet, 7, 9, 11, 13, 15.
- Off-bearer**—The man who stands behind the saw and takes away the lumber and slabs. Syn.—Tail sawyer, swamper.
- Ogee moulding**—One having a double curve formed by a concave and convex line.
- Overrun**—The difference between the lumber tally and mill scale.
- Parbuckle**—A device for loading logs. It consists of a chain or rope in the form of a sling attached to the wagon or sled.
- Partition**—Lumber used for interior partitions where both sides of the board are exposed.
- Pile bottom**—The foundation (timber or concrete) on which lumber is piled.
- Pin knot**—A knot which is sound and not more than one-half inch in diameter.
- Pitch**—The angle between the back of a tooth and a line drawn from a point of the tooth to the back of a band saw or to the center of a circular saw.
- Pitch pocket**—An opening or space between the annual rings containing pitch in coniferous trees. Syn.—Pitch seams.
- Plain sawed**—All lumber which is not quarter sawed. Syn.—Flat grain, bastard grain, slash grain.
- Pony gang**—A saw crew of two men who do their own swamping.
- Porch decking**—A tongue and grooved board, the upper face of which is grooved in order to carry off rain water.
- Quarter-sawed**—In hardwoods, when the lumber is cut parallel or nearly so with the medullary rays. In soft woods, when the growth rings do not tip more than 45° from the vertical throughout the entire length of the board. Syn.—Center sawed, comb grained, edge grained, figure grained, rift sawed, silver grained, vertical grained.
- Rip**—To cut a board lengthwise.
- Rock pine**—The Chicago name for hemlock.
- Sampson**—An upright lever used for rolling logs. It is attached to the log by a chain.
- Short length**—Lumber from 4 to 10 feet.
- Sidings**—Boards sawed from the outer portion of a log when the central part is made into lumber.
- Slack cooperage**—Containers for nonliquid products consisting of two round heads and a body composed of staves held together with hoops.
- Slat**—A sawed piece of wood $7\frac{1}{2}$ by $2\frac{1}{2}$ by $\frac{1}{4}$ inches, used in pencil manufacture.
- Small knot**—A sound knot not more than three-fourths inch in diameter.
- Snake**—To make a wavy cut in sawing.
- Snipping**—The act of rounding off the end of a log to prevent the latter from sticking in the ground. Syn.—Sniping.
- Sound knot**—One which is as solid and hard across its face as the surrounding wood and firm enough to retain its place in the board.
- Spike knot**—A knot sawed lengthwise in the board.
- Spline**—A rectangular strip of wood which is substituted for the tongue on heavy factory flooring.
- Stepping**—A grade of lumber worked to a size suitable for steps.
- Stock boards**—Of even widths, usually 8, 10, and 12 inches.

- Straight grain—A piece of lumber is said to be straight grained when the principal wood cells are parallel to its length.
- Swamp hook—A hook to be attached to a chain used for rolling logs.
- Tail sawyer—Off-bearer.
- Tally—A record of the number of pieces and grades which are cut in the mill.
- Tight cooperage—Containers for liquids consisting of two round heads and a body composed of several staves held together by hoops in such a manner as to hold liquids.
- Timber—4 inches by 4 inches, and larger dimensions.
- To box a log—To throw a log from the log trough upon the mill deck by means of a log kicker.
- To box the heart—To cut boards from all sides of the heart, leaving the latter as a piece of timber.
- To jack lumber—Means to pass up boards to the piler on top of the pile by leverage on an upright pole or a short board projecting from the front of the pile.
- To saw around a log—To cut three or more faces on a log in order to get the best quality of lumber in each cut.
- To saw alive—To make all cuts on the log parallel, without canting the log.
- Torn grain—A defect on surfaced lumber caused by the fibers of the wood being torn by the planer knives.
- Uppers—Finish lumber.
- Veneer—A thin piece of lumber cut on a veneer machine. There are three kinds of veneer, viz, sawed, sliced, and rotary cut.
- Wane—Bark or decrease in wood on the edge of board, plank, or timber.
- Washboard lumber—Poorly sawed lumber with ridges on the face of the boards.
- Woods scale—The scale of the logs made in the woods.
- Wood fiber—Narrow shavings cut from a round block of wood by a special machine.
- Yard lumber—Lumber which has been air dried.

ABBREVIATIONS.

- C. I. F.—Cost, insurance, and freight.
- F. O. B.—Free on board.
- F. A. S.—Free along side.
- F. G.—Flat grain.
- V. G.—Vertical grain.
- C. I. F. E.—Cost, insurance, freight, and exchange.
- D. & H.—Dressed and headed. A flooring strip which has been surfaced, tongued, and grooved on one side, and also has a tongue on one end and a groove on the other, so that the joints may not necessarily come over a joint.
- D. & M.—Dressed-and-matched boards, which have been tongued, grooved, and matched.
- E. G.—Edge grain.
- W. A. L.—Wider, all lengths.
- AW. & AL.—All widths and all lengths.
- 5/4, 6/4, 8/4—1½ inches, 1½ inches, and 2 inches.
- K. D.—Kiln dried or knocked down.
- S. 4S. C. S.—Surfaced on 4 sides in the 1/16-inch caulking seam on each edge.
- S. M.—Surface measure.
- S1 S. 1E—Surfaced on one side and one edge.
- T. B. & S.—Top, bottom, and sides.
- T. & G.—Tongued and grooved.

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CHARLES J. BRAND, Chief



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WOMEN'S RURAL ORGANIZATIONS AND THEIR ACTIVITIES.

By ANNE M. EVANS,
Investigator in Women's Rural Organizations.

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WOMEN'S RURAL¹ ORGANIZATIONS ARE NUMEROUS AND VARIED.

The rural telephone, better roads, the automobile, and rural tree delivery have greatly facilitated communication in rural districts. Women whose homes are on the farms are taking advantage of the improvement in means of communication and are endeavoring in an organized way to further the development of every phase of activity which will mean better home life on the farm, broader and bigger agricultural opportunities for the future, and an ideal rural community life.

Organizations have been small and simple, but they are permeating country life. For example, in one Southern State having three-fourths of its land area in farms there are over 500 women's rural organizations. The organizations represented are: The Homemakers' Clubs, the Parent-Teacher and School Improvement Associations, the Daughters of the Confederacy, the Cooperative Clubs, the Eastern Star, the State Federation of Women's Clubs, and the Woman's Christian Temperance Union. In addition there are a number of ladies' aid and missionary societies, and neighborhood and family clubs not belonging to any of the county or State organizations.

¹ All organizations located in places of less than 2,500 inhabitants are considered as "rural." This is in accordance with the definition of rural territory adopted for the Thirteenth (1910) Census.

A single organization, of national character and not usually considered rural in its interests, the General Federation of Women's Clubs, counts among its locals in the open country, in hamlets, and

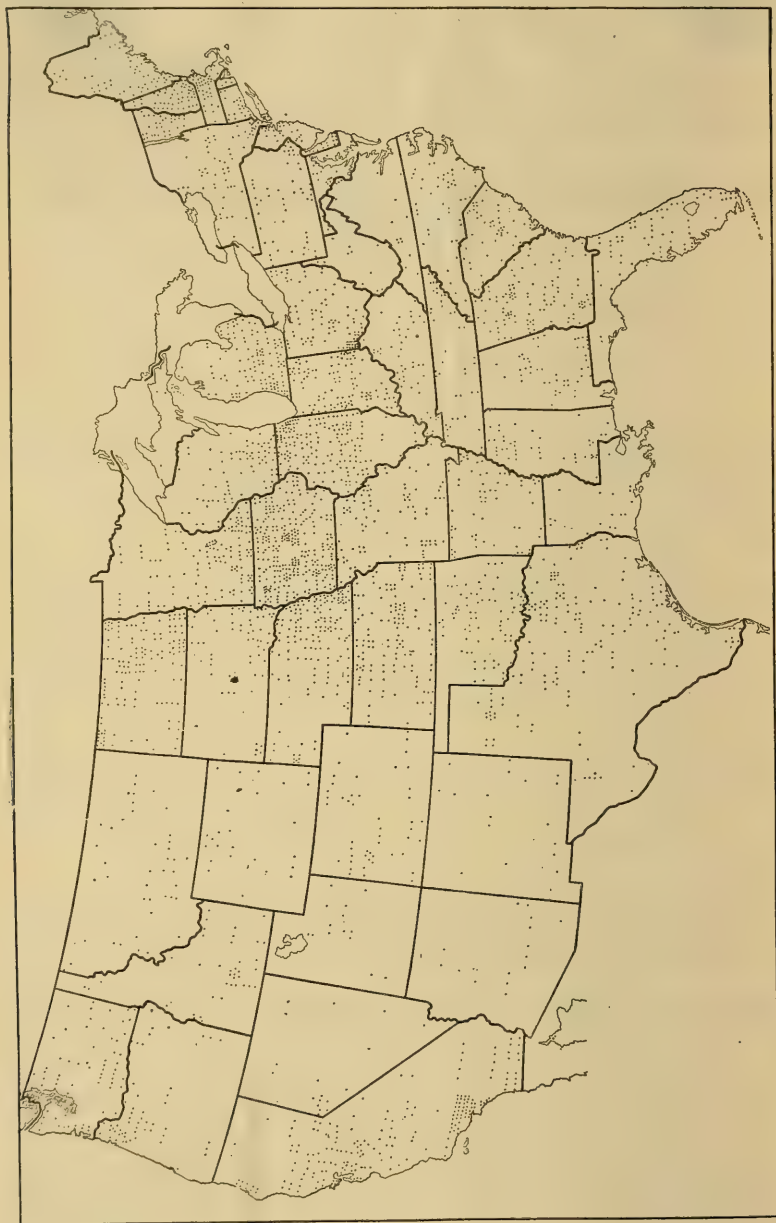


FIG. 1.—State Federation Clubs in places of less than 2,500 inhabitants. Each dot represents one club.

in small towns, over 3,500 women's organizations. (See fig. 1.) The National Woman's Christian Temperance Union has twice this number. (See fig. 2.)

There are two national farm women's organizations, the National Farm and Garden Association and the National Congress of Farm Women. Adequate means of communication is one of the most

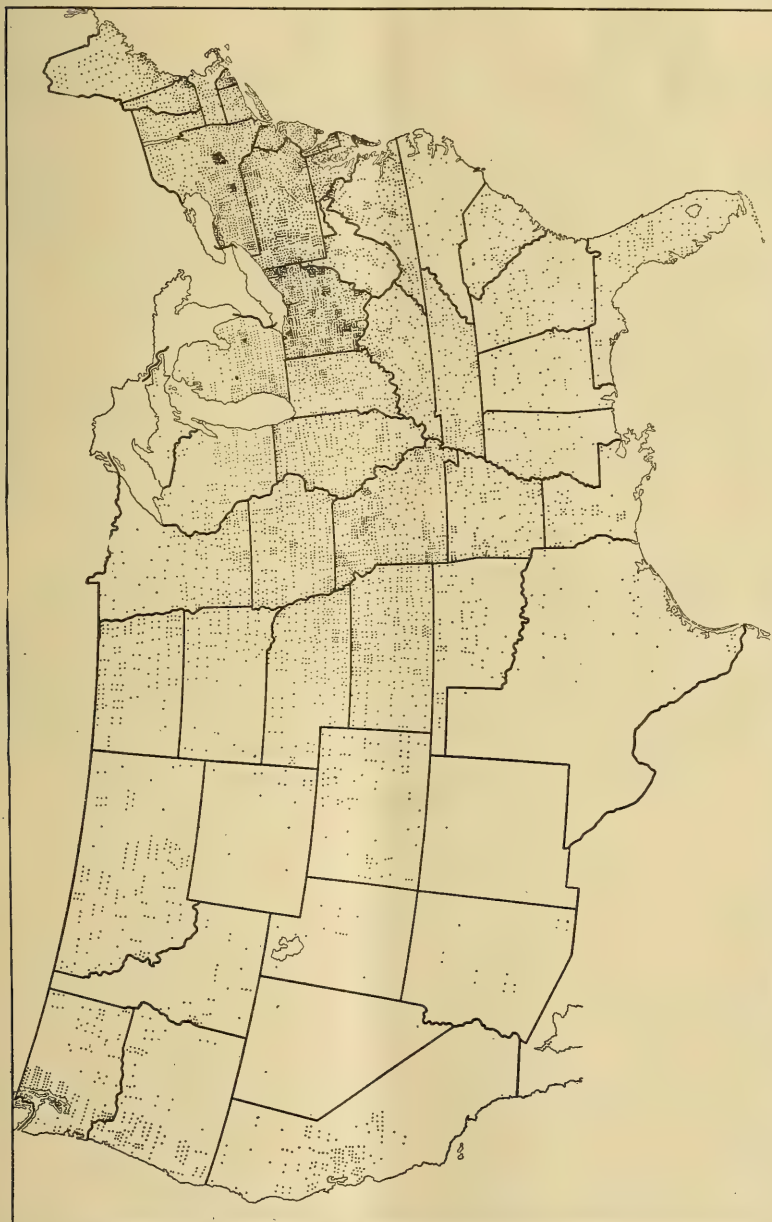


FIG. 2.—Woman's Christian Temperance Unions in places of less than 2,500 inhabitants. Each dot represents one union.

difficult problems of these organizations. The first-mentioned of these two organizations publishes a quarterly bulletin and holds annual and semiannual meetings in widely separated parts of the

country in its effort to meet this difficulty. The National Congress of Farm Women has thus far relied upon annual meetings, but it is felt that this is not adequate.

There are State organizations of farm women in Illinois, Iowa, Kansas, Ohio, Missouri, Michigan, Oklahoma, Texas, and Utah, varying in activities. In establishing these State organizations assistance has been rendered by State appropriations, as in Illinois; by farmers' organizations, as in Michigan and Illinois; by the extension departments of the State agricultural colleges, as in Iowa and Missouri; and by farm papers, as in Ohio, Oklahoma, and Michigan.

In some States the State Federation of Women's Clubs considered holding separate sessions of women interested in farm and in city problems, but the interests of the homemakers, whether they lived in the city or in the country, were found to be so much alike that the idea of separate meetings was abandoned.

County organizations of farm women are more active than State or National organizations. The family clubs in Minnesota and Michigan bring the women of the county together. In many instances this has resulted in a county organization of women belonging to the farmers' clubs, such as the County Women's Club which meets at Hastings, Minn.¹ In Cerro Gordo County, Iowa, the county fair brought to the women a realization of their power to help the county, which resulted in a county federation of a number of local clubs. The increased interest which farm women have been taking in the State Federation of Women's Clubs has resulted in the organization of county federations in many States and the same recognition is given them as is given city federations. A list of counties in which there are county federations of women's clubs is given below:

Counties having federations of women's clubs.

Illinois:	Maine:	Michigan—Continued.
Kane	Kennebec	Lenawee
Indiana:	Knox	Oakland
Delaware	Maryland:	Oceana
Jay	Montgomery	St. Joseph
Madison	Michigan:	Van Buren
Randolph	Allegan	New York:
Iowa:	Berrien	Allegany
Cerro Gordo	Cass	Chenango
Clinton	Eaton	Cortland
Kansas:	Genesee	New Mexico:
Marion	Ionia	Dona Ana
Morris	Jackson	Ohio:
Osage	Kalamazoo	Huron

¹ The names of clubs given are those of which the writer has had opportunity to gain personal knowledge. They are given as illustrations. Many other clubs which have not been mentioned are doing a work equally important.

Oklahoma:	Pennsylvania—Continued.	Texas—Continued.
Grady	McKean	Gregg
Logan	Montgomery	Hidalgo
Kiowa	Westmoreland	Lubbock
Garfield	Texas:	Washington:
Harmon	Armstrong	Grays Harbor
Pennsylvania:	Bee	Skagit
Delaware	Cameron	Snohomish
Erie	Collin	Yakima Valley
Greene	De Witt	

The clubs of the Department of Household Science of the Illinois Farmers' Institute have county meetings. One of the national associations has its work organized by counties. In State meetings members and delegates from the same county are seated together and reports of the work accomplished are made both by the county presidents and by the State chairman. Rural clubs in the country around the county seat frequently form a county organization to cooperate in establishing a rest room for farm women or in working for a woman county agent or a county appropriation for some other educational or charitable purpose.

ORGANIZED EFFORT OF WOMEN DEVELOPS HOME LIFE.

Through baby-welfare conferences and contests arranged by clubs, mothers study the development of their children and have the opportunity of securing instruction on health subjects from the competent physicians whose services for this purpose can be secured without expense. The civic committee of the Montgomery County Federation in Maryland arranged for such a welfare conference at the county fair. Twenty-five children were examined, of whom many were found to be subnormal, the physician reporting malnutrition as one of the main causes of the trouble. Mothers could remedy this to some extent by planning a better balanced diet for their children. Several national organizations of women are encouraging the celebration of baby week, which is already observed yearly by hundreds of farm women's clubs. A club of country women living near Renwick, Iowa, celebrated baby week by cooperating with two other local women's clubs in holding a baby contest in Renwick. The State Agricultural College, through its extension service, detailed a physician to make mental and physical examinations, and a specialist to speak on child welfare, and local physicians volunteered their assistance. The rural women were notified by telephone, notices were published in the local paper, and prizes of five-dollar savings deposits were offered for the boy and girl between the ages of six months and three years found to be in the best physical condition. To defray incidental expenses each member of the club voluntarily contributed 30 cents. The prizes, equipment, and rooms for exami-

nation, as well as the services of doctors and nurses, were donated. Such contests are promoted by a single club or by several cooperating, but are most successful when open to all mothers and children in the township or county, regardless of club affiliation.

The study of foods at club meetings raises the standard of family health and tends to remove physical defects caused by malnutrition. The woman's club is often the only channel open to the married woman through which to continue the study of such subjects.¹ The Troy Culture Club, of Eagle Grove, Iowa, was organized for this purpose in 1910. Meetings were held every other week in the farm homes. The committee for the day prepared the food and looked up scientific facts to be discussed. Various methods of preparing different vegetables were shown in season. The leavening value of beaten eggs in omelets and in cake was studied in comparison with yeast and baking powder. Types of food constituting a balanced ration for the family were studied. These clubs form at present the most direct channel through which to promote the conservation of wheat and the use of war breads and meat substitutes.

More varied diet in many farm homes has been made possible through canning clubs, which are to be found in every State of the Union and which are especially successful in the South. Vegetables of all kinds, fruits, and even meats, are canned for home use.²

The promotion of penny savings by women's organizations has done much to encourage thrift in farm homes. The Harvard Woman's Club, a rural club in Massachusetts, instituted a stamp-saving campaign. A committee of two was appointed to manage the work and 35 children have established savings accounts. The Pepperell Women's Club, in Massachusetts, including farm women as members, though not strictly rural, started a work of this kind in December, 1916. In six months the children had saved \$400. They bring their pennies to the school, give them to the teacher or to some responsible club woman, who opens an account in the child's name at the bank as soon as \$1 is saved.

Labor-saving devices have been installed in many homes and new ideas of household efficiency developed through club work. At Potomac, Md., a number of such devices were constructed and exhibited at the community fair held in the schoolhouse. In order to prevent continual stooping to pick up clothespins while hanging out the washing, a clothespin bag was made on a coat hanger to slide along the line. A homemade fireless cooker³ was shown as a device

¹ Most of the extension departments of the State agricultural colleges give assistance in organizing clubs of this kind and furnish program material and trained demonstrators in domestic science.

² Bulletins on canning may be secured from the United States Department of Agriculture and from the State agricultural colleges. Farmers' Bulletins published by the Department of Agriculture are: No. 839, Home canning by the one-period cold-pack method; and No. 853, Home canning of fruits and vegetables, 1917.

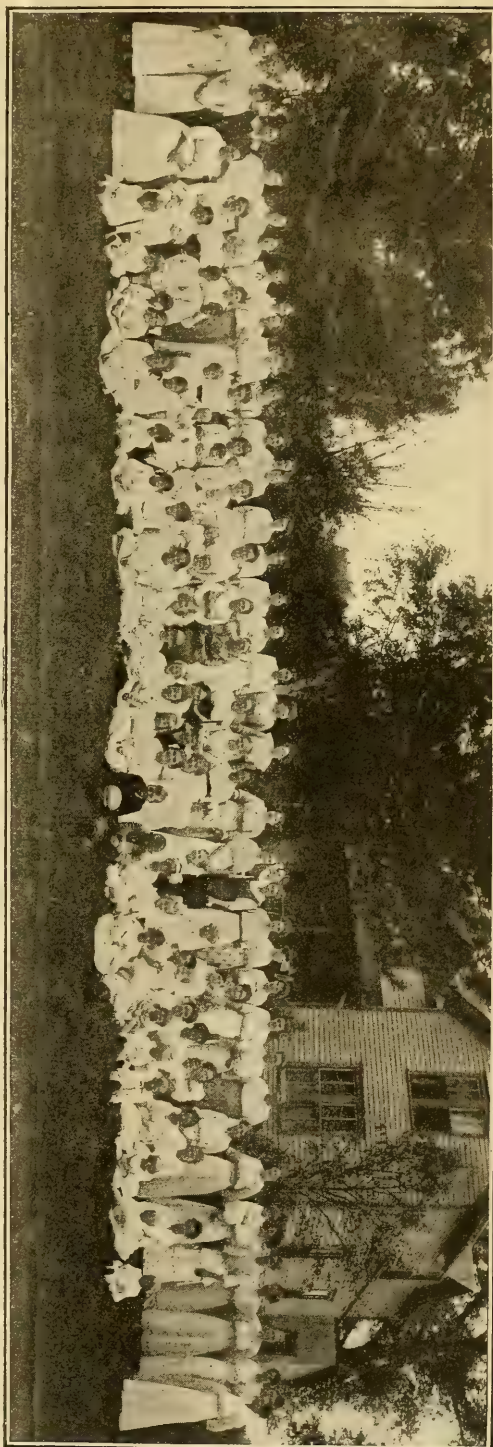
³ Directions for constructing iceless refrigerators and fireless cookers may be found in Farmers' Bulletin No. 771, Homemade fireless cookers and their use; and Farmers' Bulletin No. 927, Farm home conveniences.

for cooking foods while attending to other duties. Another exhibit was a homemade white-enamelled iceless refrigerator¹ designed to save unnecessary steps and lifting in putting food into the well for cooling. These and similar devices free the home maker from much unnecessary routine work and give her more opportunity to attend to other home problems.

Clubs organized for purely social purposes often become instrumental in interesting the members in home economics and community work. This is illustrated by a social club near Wyanet, Ill. After holding social meetings for two years in the homes of the members they re-organized as the Wyanet Household Science Club. A five-day school of domestic science has been secured from the university, at a cost of about \$15; papers on home topics are read at the meetings, with an average attendance of 45; and occasional outside lecturers are secured. Figure 3 shows an afternoon joint meeting of two women's rural clubs.

Such activities as these reduce the sense of drudgery inevitable to the wo-

FIG. 3.—Joint meeting of two Women's Rural Clubs.



¹ See footnote 3, page 6.

man who works alone every day. They bring women together for discussion of the problems of daily life in such a way that they may return to their work with a sense of companionship, renewed enthusiasm, and interest in their accomplishments.

COUNTRY WOMEN COOPERATE FOR BROADER AGRICULTURAL OPPORTUNITIES.

Women are cooperating in practical efforts to solve agricultural problems. Personal experiences in seed selection for the production of corn were discussed before the National Congress of Farm Women at its last annual meeting by a delegate who has had marked success in corn and hog raising. Some women of rural clubs in Iowa have been experimenting with seed selection and germination. Various women's colleges located on large farms have arranged for groups of students to remain on the farms during the summer vacation to learn to operate the machinery and to study farm management. The National Farm and Garden Association has published in its official bulletin articles about the work done by members, describing various agricultural activities in which women farmers have been successful. Mention is made of the success of a woman at Whitesbog, N. J., as a grower of cranberries and large blueberries; of one at Wilmington, Del., in raising prize poultry; and of another at Newtown, Pa., who runs a large dairy farm and raises Ayrshire cattle. This association also assists in securing suitable positions for women trained in agriculture and for other women wishing to do agricultural work.

To encourage tree planting and flower growing, trees, plants, and roots have been collected and distributed by women's rural clubs. The Big Timber Woman's Club, of Montana, distributed among the women of the town 70 dozen asters for planting. To a community fair in Arkansas, promoted by a number of rural community clubs, each woman brought seeds, cuttings, or roots from all of the flowers grown on the premises. These were not sold, but exchanged, thus introducing a wide variety of plants for the beautification of all the homes in the community. In order to earn the money for trees and shrubbery the Women's Civic Improvement Club, of Huntley, Mont., planted beets in the acre and a quarter of ground which it wished to develop into a park.

Through the study and dissemination of information relating to marketing, women's organizations are assisting in agricultural development. At a federation meeting of the Logan County Farm Women's Clubs of Oklahoma a portion of the time was devoted to a discussion of problems connected with the grading, sorting, and packing of peaches for market, as the women assisted in harvesting the peach crop. Again, marketing the apple crop was similarly discussed by the women's clubs at Sunnyside, Wash. A farm woman's club in Denton, Md., whose membership comprises many

progressive farm women in the locality, made a study of the extent to which members of their club were selling farm products. It was found that during the past year seven members had sold nearly \$1,000 worth of farm products, including eggs, chickens, canned goods, pigs, and butter. Some members were cooperating in shipping eggs, and others were carrying eggs a number of miles for shipment when they could have shipped with their friends near by. One member was securing high prices for infertile eggs and had more customers than she could supply, while others were willing to assist in supplying infertile eggs to the trade. The advantages of various methods of marketing were discussed by members from their own experiences.

Practical experiments in marketing have been carried on by a number of women's rural clubs in Pike County, Ill., which have aided members in marketing farm products, especially eggs and chickens. The rural club encouraged the work among its members and secured names of prospective buyers from clubs of city women, and while neither city nor country clubs assumed any financial responsibility, they stood for upright dealings on the part of members and thus helped to establish the necessary confidence between people personally unknown to each other.

By creating an interest in natural history and in agricultural education among girls and boys, women's rural clubs are endeavoring to prepare them to take advantage of agricultural opportunities already open. Agricultural shows and exhibits stimulating competition in production are fostered by rural clubs in many localities. In Massachusetts a woman lecturer of a local grange arranged for such an exhibit, where 59 varieties of grasses were displayed, together with rare woods, such as blue beech and ironwood, to be found in the locality. The bird department exhibited lists of 90 birds which had been seen in the neighborhood, and the flower department showed 160 classified flowers. Junior Audubon societies have been organized by women's clubs, the children holding classes and studying birds under the direction of members of the clubs. While these studies may not in all cases have direct bearing upon agricultural production, they frequently stimulate an interest in practical agriculture. The Women Farmers Club of Missouri has offered an annual scholarship of \$25 for the study of practical farming to the girl who scores highest in planting and cultivating a certain amount of ground according to the rules of the boys' corn contest.

Many clubs are instrumental in obtaining better opportunities for reading. Volunteer librarians gather Government bulletins on agriculture and other material of interest in rural communities, and lend them to members of the community. The women's clubs of the State of Montana have cooperated in what is called a vocational

congress, the object of which is to present to girls throughout the towns and rural districts of Montana the vocational opportunities open to women. The congress includes conferences on agriculture, home economics, art, education, and newspaper work. Each club selects a representative girl from the high school in its district and pays her traveling expenses to and from Bozeman so that she may attend the vocational congress which is held at the State College. The college bears the expense of the speakers and the meetings, and the club women in the town of Bozeman entertain the delegates in their own homes during the three days' visit. This has not only benefited the girls, but their reports to the clubs sending them have been the occasion of joint meetings of local clubs and of wider interest in vocational opportunities.

The efforts of country women in cooperating for broader agricultural opportunities have been positive and constructive. They have shown a desire to work out agricultural problems in a fundamental way which will enable them to maintain high standards of home life on the farms.

FARM WOMEN'S ORGANIZATIONS PROMOTE COMMUNITY LIFE IN THE COUNTRY.

With home conveniences on the farm the women have time to consider community needs and to plan for community development. Farm women have been able to give much time to those things which they believe helpful to all, and their activities have been so numerous that those mentioned here can serve only as illustrations.

Rest rooms for farm women ¹ have been established in many States through the joint efforts of local clubs of rural women, in cooperation with organizations of women in town, chambers of commerce, and public officials. A room is maintained in a location convenient to country women for their own use when in town. Couches, easy chairs, reading material, and sanitary conveniences are provided.

Community fairs ² or school fairs have been promoted by farm women in Montgomery County, Md., St. Joseph County, Mich., and in nearly all other States. The purpose is largely educational, but the meetings serve as opportunities in some localities to introduce athletic contests as well as industrial and agricultural competition. A county federation of women's clubs in Maryland arranged for an automobile pageant at the county fair, with about 20 beautifully decorated automobiles, some of them representing various women's organizations.

Home economics and manual training are often introduced into the rural schools as a direct result of club work. The Federation

¹ See Agricultural Yearbook Separate 726, Rest Rooms for Women in Marketing Centers.

² See Farmers' Bulletin 870, The Community Fair.

of Rural Clubs in Grand Junction, Colo., provided funds for the equipment for manual training in one rural school and for domestic science in another, the school trustees agreeing to provide the rooms and the instruction in both instances. In a rural community in New England, club women taught sewing to the children after school so successfully that in the latter part of the year time was given during the school day for this work, and provision was made for paying for such instruction from public funds. The Pettis County Home Makers' Club, a Missouri rural club of nearly 200 women, was instrumental in introducing domestic science into 10 of the rural schools in that county. Women's organizations in a number of Western States have promoted the building of homes in connection with country schools, in order that adverse boarding conditions in the country might not deter teachers from accepting positions in rural schools.

Entertainments to which all members of a community are invited are frequently given by rural club women. At Renwick, Iowa, these take the form of evening socials for the entire family, more than 100 attending. In another locality an annual picnic is held, to which everybody is invited, each county club contributing to the general entertainment; the Midland County Club, for instance, agrees to furnish a tableau representing the Thirteen Colonies. Sometimes a club secures a speaker to give an evening address in the church, in the Grange hall, or in the community building. Amateur theatricals and rural pageants, such as the one held in Thetford, Vt., are arranged for by rural club women. In one county an annual hunt is held; two leaders choose opposing teams and a score card is planned to encourage only the killing of farm pests. The women join in the hunt and provide the dinner. Community Christmas trees¹ are held in many rural places. In Shelby County, Tenn., there were seven such entertainments one year. The trees were trimmed by the school children with homemade decorations. The programs consisted of the singing of Christmas carols, Testament reading, and stories told by the older people of their first experiences at Christmas. Those born in foreign lands told how Christmas was observed there.

Community singing has found general favor. The Farm Women's Club of Edmond, Okla., started community singing in the school-house. A competent person to direct and a suitable place for meeting appear to be the chief requirements. Club songbooks and official club songs frequently develop a social spirit.

The interest in rural history, which some rural clubs are promoting, helps to develop community life. Members of the Women Farmers' Club in Missouri, living in adjoining counties, arranged for markers to

¹ See report entitled "Community Christmas Trees," published by the Pan-American Union, Washington, D. C.

be placed on the old Santa Fe Trail and also on the road which now follows the trail blazed by Daniel Boone on his way to Salt Lick in Howard County. Neighborhood celebrations and dedications roused community interest in these events. A community history is being compiled by an organization of men and women in the progressive agricultural community of Sandy Spring, Md., of which organization the president, secretary, and historian are women. Each year a community historian is appointed to write a record of the achievements of the community for the current year, which is read at the annual mass meeting. Several volumes of this history have been published. Other rural clubs, such as the Evergreen Daughters of Ceres, near Eagle Grove, Iowa, are studying the State laws affecting women and children in connection with the study of town and State history.

Women's clubs have been instrumental in securing better roads. Dinners were served to road workers by the women of the Clarksville Pike Social Club, near Hopkinsville, Ky. In a county in Iowa, where "a Travel on Gravel" campaign was in progress, the Troy Culture Club, near Eagle Grove, furnished meals for all volunteer workers on the roads in that community. In another locality the Mothers' Club furnished lunches for the men on "Road Working Day." Members of the Missouri Women Farmers' Association pledged themselves to furnish teams for work on roads in their localities and to drag the roads in front of their own homes.

Rural cemeteries have been improved and kept in good condition through the activity of rural club women. The work of the Women's Cemetery Association of Dysart, Iowa, may be cited as an example. This association has a membership of over 150 women. The cemetery was given to the town some years ago, but no one attended to it. The undertaker sold the lots. Several members of the community felt that the women would be able to improve the general appearance of the grounds and asked that they undertake it. The women in return invited all public-spirited people to meet in the cemetery one evening and help clear away the débris. Subsequent meetings were held and pledges were made to meet the expense of improving the cemetery. Reports of the progress of the work were given at monthly meetings, and though only a few attended these meetings, all were enthusiastic about assisting in the work when called upon to do so. The women undertook to sell the lots themselves, raising the price from \$10 to \$25 and more, depending upon location. Money was raised in this way and through popular subscription, so that now they have over \$2,000 in the treasury. A caretaker is hired for the summer months at a salary of \$45 per month.

Clean-up and paint-up campaigns have been popular in the country as well as in the city. At Glendale, Ariz., the women's club of 75 members offered prizes for the largest refuse heaps. One hundred

and sixty school children collected 60 such heaps, which were removed by the town authorities. Fences and trees are whitewashed, and fly and moth campaigns are successfully carried on by women's clubs.

Arbor Day is celebrated in many localities by planting shade trees in the school yards and on country roads. A county in California planted a large number of shade trees on country roads, every woman's club in the county being responsible for certain portions of the road. The courtyard in Ashland City, Tenn., was turned into a park by the woman's club there.

Women's clubhouses are frequently used as community centers. A recreation hall was built by the Ladies' Literary Society, a rural club near Exeter, Me., as early as 1865. It is still in existence and has been managed by the same organization of women since its construction. There is a stage for speaking and dramatic entertainments, the Grange meets here, the young people may secure the hall for social gatherings, and equipment for cooking and serving is provided. On a reclamation project in Arizona a splendid type of rural club undertook the building of a clubhouse immediately upon being organized, as there was at that time no available meeting place large enough for public gatherings. It is said that at the time of the organization of this club in 1907, when the meetings were held in the members' homes, the members were very widely scattered and drove on trails and through sagebrush to the meetings, some driving as far as 17 miles. Funds were raised by subscription for the clubhouse, the business men contributing a substantial sum. The families of the members helped, and when the time came for construction much of the hauling and actual work of building was done by them. The clubhouse was used at once for a union Sunday school and has always been available without charge for any community enterprise. Its maintenance is provided for largely through rentals to the young people for their social gatherings. The Heaton Point Household Science Club, in Illinois, unable to build a clubhouse, bought 100 trays, spoons, and folding chairs to be used by any person in the community for special entertainments or for any large gathering.

Women's rural clubs have done much to further the employment of trained workers for the county, such as women county agents, county nurses, and county social service workers. The woman State agent for Mississippi has said that the women's clubs in that State have been constant and earnest supporters of woman county agent work in home economics. They have given financial aid, used their influence to secure appropriations, bought canning club products, and given the work a prominent place on their programs. In St. Joseph County, Mich., money was raised through the sale of Red Cross stamps and in other ways to pay part of the salary of a county nurse. In some rural communities the women's organizations have

been able to arrange for medical inspection in rural schools. In Wolfeboro, N. H., the women's club induced the local dentist to inspect without charge the teeth of all school children, including those from rural and village schools. Volunteers from the women's club attend to the clerical work and funds are furnished for dental work when necessary. A county nurse for public health work is employed by a county social welfare league in Montgomery County, Md. All local women's organizations in the county which wish to work for health improvement are invited to belong to this social welfare league. The nurse receives a salary of \$100 per month and works with the county health officer. Her particular work the first year was directed toward reducing the death rate from tuberculosis and improving general sanitary conditions. The women's club of Pepperell, Mass., paid the salary of a trained nurse for a short time for the purpose of interesting the public in a district nursing association. This latter association is composed of men and women and is supported by \$1 membership fees, with an appropriation of \$200 from the town, together with fees of 25 cents an hour for those who can pay for the service. A number of Red Cross nurses have been employed under the rural nursing department of the American Red Cross and the local women's rural clubs have greatly assisted in promoting the success of the work. Rural women's organizations have given some assistance in making provision for county social service workers, such as county probation and juvenile court officers and children's aid society workers. They have also cooperated with these workers in caring for the dependent children of the county.

Philanthropic work is carried on by many women's rural organizations. The farm woman's free time, taken while resting from more strenuous labor, is frequently spent in knitting, crocheting, and sewing for sales to raise funds for charitable and religious purposes. The Congregational Ladies' Aid of Huntley, Mont., has contributed \$1,000 in this way during the past seven years toward the support of the church. Barrels of canned fruit and crates of eggs, besides cash donations, are sometimes sent to local orphanages. An "Egg Day" is sometimes held, when each member contributes a dozen eggs or more, which are packed in cases at the club meetings. This has been done by farm women's clubs in many States, among which may be mentioned the Norden Ladies' Aid, on a Montana reclamation project, and the Boone Township Club, in Iowa. At Glendale, Ariz., the eggs were contributed at Easter and used for an egg hunt in the town park. Each child paid a small fee and the money was used for philanthropic purposes. A room in the town hospital is maintained by a rural club in Iowa. Seventy-five dollars was spent for the original equipment and special conveniences are added from time to time. War sufferers are assisted by local federations of women's clubs.

Such an organization in Traer, Iowa, through donations received from clubs in Tama County, contributed a carload of new clothing for relief in Belgium. A hundred dollars in money was raised in this town of less than 1,300 inhabitants by holding a Belgian tag day. The Home Improvement Club, a woman's country club near Clear Lake, Iowa, was instrumental in donating a carload of corn for Belgian relief. The club arranged for newspaper notices and church announcements requesting all who were willing to contribute to bring the corn to the farmers' cooperative elevator, from which it was shipped. Club members personally gave corn to the value of \$100. Farm women have spiritedly undertaken Red Cross work, sewing, knitting, procuring wool for others to knit, collecting clean linen and cotton goods, and preparing bandages. Some of this work is best done under the direct supervision of the local Red Cross chapter.

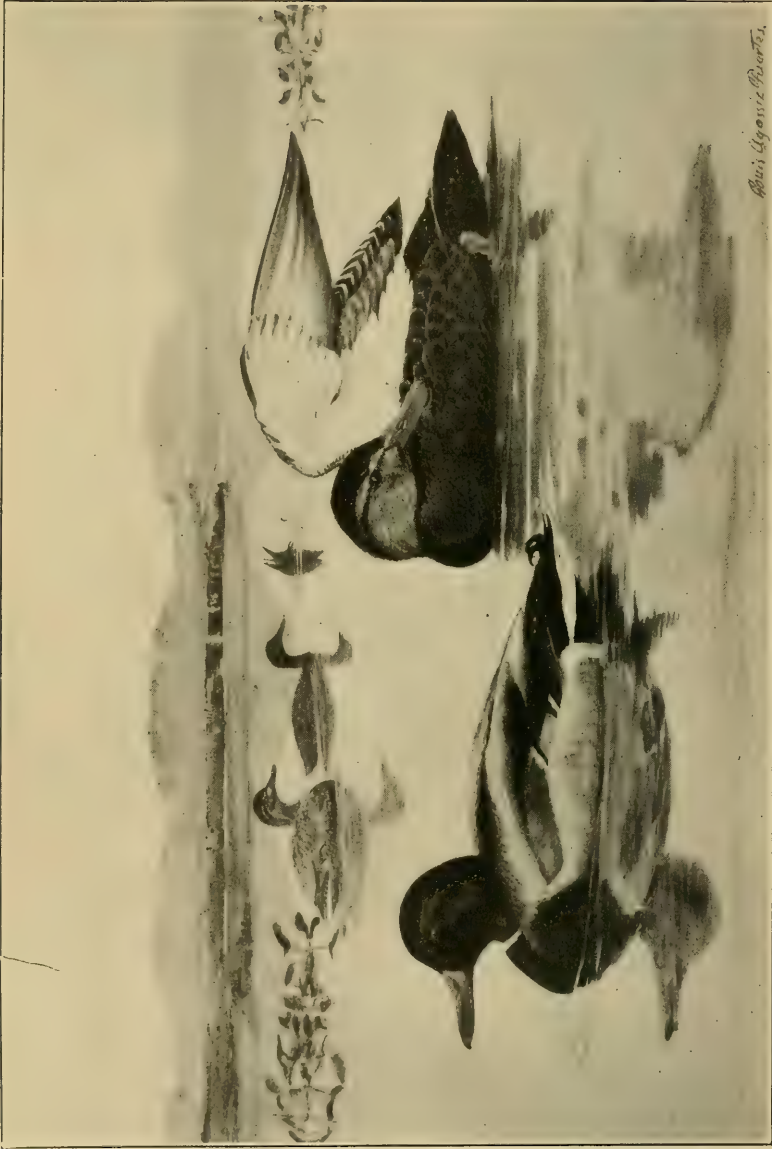
The club work directed toward improving community life in the country has been varied but constructive and has been planned to include as workers all who wish to help. The results have been beneficial to the whole community and have tended to promote a community interest in country life and country problems and a closer intimacy with national needs.

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MALLARD AND BLACK DUCKS.
Lower figures, males; upper, females.

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E. W. NELSON, Chief.



Washington, D. C.

PROFESSIONAL PAPER.

December 23, 1918

FOOD HABITS OF THE MALLARD DUCKS OF THE UNITED STATES.

By W. L. McATEE, *Assistant Biologist.*

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INTRODUCTION.

A knowledge of the natural feeding habits of mallard ducks is of value in connection with the propagation of the species in a semi-domesticated condition, as these ducks are used more commonly for this purpose than are any others. It is especially useful also in relation to the improvement of bodies of water and marshes as feeding grounds for wild ducks.¹

The wild ducks ordinarily occurring within the United States are at present considered to represent 39 species, distributed among 22 genera. They are divided into three groups: The mergansers (*Merginæ*), known also as fish ducks, or sawbills; the river ducks (*Anatinæ*), also called shoal-water, puddle, or tipping ducks; and the sea ducks (*Fuliginæ*), also called deep-water, or diving ducks. Although food preferences vary in each of these groups, those of the mallards are fairly representative of their group—the river ducks. The mallard genus, *Anas*, comprises three species which are among

¹ For specific information on this topic see Bull. 205, U. S. Dept. Agr., Eleven Important Wild-Duck Foods, in which are discussed musk grass, duckweeds, frogbit, thalia, water elm, swamp privet, cograss, wildgeon-grass, watercress, waterweed, and coontail; pp. 25, figs. 23, May 20, 1915; also Bull. 465, Propagation of Wild-Duck Foods, in which are discussed wild rice, wild celery, pondweeds, delta potato, wapato, chufa, wild millet, and banana waterlily; pp. 40, figs 35, February 23, 1917.

NOTE.—This bulletin presents a technical study of the food habits of three species of mallard ducks: The mallard, the black duck, and the southern black duck. The vegetable food preferences exhibited will serve as a guide to certain wild-duck foods that may be propagated when it is sought to increase the numbers of these valuable game ducks, either in the wild state or in domestication.

our most valuable game ducks and includes the most important single species—the common mallard (*Anas platyrhyncha*). The others are the dusky or black duck (*Anas rubripes*) and the southern black duck (*Anas fulvigula*).

These river ducks rarely dive so as to disappear entirely beneath the water, but obtain their food in shallows by dipping the head and neck or by submerging all of the body but the tipped-up tail. Vigorous paddling with the feet is needed to maintain the latter position in the water. The food usually is obtained within 12 to 16 inches of the surface, and as a result river ducks obtain fewer of the underground organs of aquatic plants than the diving ducks. These root systems of the plants include the rootstocks, stolons, tubers, and winter buds, which are stocked richly with nutriment. However, the river ducks wax fat by their own way of living, and although they are distinctly successful foragers, expediency seems to be their rule, as they are more nearly omnivorous than any other ducks.

MALLARD.

(*Anas platyrhyncha*.)

The mallard (see frontispiece) probably is the most abundant wild duck in the world, and its range covers the entire northern portion of the earth. Wherever it occurs it is popular and is usually the favorite waterfowl. Various races have claimed it for their own, and in consequence it has received such names as English duck and canard français (French duck). Other common names are wild duck, green-head, gray mallard, and stock duck. The last name refers to the fact that the mallard is the source of most of the breeds of domesticated ducks. That it is possible under controlled conditions to produce mallards typically wild both in appearance and behavior has been taken advantage of on duck farms, where birds are reared both for market and sport.

The ease with which the mallard can be bred makes it the best species for wild-duck farming. This is an industry which should be developed as extensively as possible, in order to supplement the decreasing natural supply of game. The mallard is not only susceptible of great increase by game farming, but also may very easily be assisted to increase in the wild state. Its breeding range is so extensive that, at least in the northern half of the United States, where local conditions are suitable, strict protection throughout the spring almost certainly will induce it to nest.

Its beauty and popularity, hardiness, adaptability, and fecundity fit the mallard as no other duck is fitted to be the game duck of the future. Upon it should be centered a large share of the interest in duck farming and wild-fowl protection. Whatever is learned about

increasing the numbers of the mallard and whatever is done to protect and preserve it undoubtedly will prove of benefit to many other species of wild ducks.

FOOD HABITS.

A total of 1,725 gizzards of the mallard, many of them accompanied by well-filled gullets, have been examined. Twenty-five were collected in April, August, and September, but not being enough fairly to represent the food in these months were not tabulated. One hundred and forty-seven stomachs were examined¹ after ascertaining the percentages, which as quoted in the following pages are derived from analyses of the contents of 1,578 stomachs.

These were collected in 22 States and in 2 Canadian Provinces. Louisiana is much more heavily represented than any other State, with Arkansas, Wisconsin, Texas, and Florida next in rank in the order named. The over-representation of Louisiana and Arkansas tends to give undue importance to the duck foods common in those States. This is especially noticeable with regard to products of plants of cypress swamps.

Some of the stomachs of mallards were interesting on account of the large numbers of individual objects they contained. For instance, one collected at Hamburg, La., in February, revealed about 28,160 seeds of a bulrush (*Scirpus cubensis*), 8,700 of another sedge (*Cyperus ferox*), 35,840 of primrose willow (*Jussiea* sp.), and about 2,560 duckweeds (*Lemna* sp.) as the principal items, a total of more than 75,200.

Another stomach collected at the same locality in December contained no fewer than 102,400 seeds of primrose willow (*Jussiea leptocarpa*), besides a number of other items in smaller numbers. The seeds in this stomach if sowed one in a place and a foot apart each way would suffice for 2½ acres of ground.

About one-tenth (9.47 per cent) of the food of the mallard is derived from the animal kingdom and nine-tenths from the vegetable.

VEGETABLE FOOD.

Approximately nine-tenths (90.53 per cent) of the entire contents of the 1,578 mallard stomachs examined was derived from the vegetable kingdom. The largest proportion of the food drawn from any single family of plants came from the sedges and amounted to 21.62 per cent of the total. Grasses rank next in importance, supplying 13.39 per cent; then follow smartweeds, 9.83; pondweeds, 8.23; duckweeds, 6.01; coontail, 5.97; wild celery and its allies, 4.26; water elm and hackberries, 4.11; wapato and its allies, 3.54; and acorns 2.34 per cent. Numerous minor items make up the remainder.

¹ By E. G. Holt and D. C. Mabbott.

SEDGES (21.62 PER CENT).

Practically all the sedges contribute to the diet of the mallard. Their fruits, or akenes (the seeds with their immediately investing coats), are of most importance, although the stems, leaves, root-stocks, and tubers also are eaten. Seeds or other parts of bulrushes were found in the greatest number of stomachs. Unidentified bulrush seeds occurred in 540 gizzards, from 400 to 1,200 in some. The akenes of river bulrush (*Scirpus fluviatilis*) were identified in 45 stomachs, and those of *Scirpus cubensis* in 286. No fewer than 28,160 akenes of the latter species were obtained from the crop and gizzard of a single mallard. Akenes of sedges of the genus *Fimbristylis* occurred in 279 stomachs, the largest number in any one being 1,000. Eighty-seven hundred seeds of a *Cyperus* were taken from a single gizzard; tubers of these sedges also were found. Saw grass (*Cladium*) is rather important among the sedges fed upon by the mallard, and its seeds were identified in 246 stomachs, 1,100 being the largest number found.

GRASSES (13.39 PER CENT).

Wild rice (*Zizania aquatica*) is the most important of the grasses fed upon by the mallard. The value of this plant as a duck food is not exaggerated in popular opinion, and it is unfortunate that the plant is almost as erratic and disappointing in its responses to attempts at propagation as it is valuable as a duck food in the places it chooses to grow. Wild rice was found in 91 of the stomachs examined for this report, and no fewer than 1,200 to 2,400 kernels had been devoured by single birds. The kernels are sometimes taken in sprouting condition, and the leaves of the plant occasionally are eaten.

Among the more important of other wild grasses represented in the diet are: Wild millet (*Echinochloa crus-galli*), switch and crab grasses (*Panicum*), rice cut grass (*Homalocenchrus*), salt-marsh grass (*Spartina*), and white marsh or cut grass (*Zizaniopsis*).

Grain, which is largely produced by plants of the grass family, may best be considered in the present connection. Oats, corn, barley, wheat, buckwheat, and rice were found and together constitute 2.99 per cent of the total food. Rice only was certainly gleaned by the birds from cultivated fields and all of it was waste. Mallards eagerly feed on rice in the shock when opportunity occurs. Thus in 1917, when various factors delayed harvesting until the arrival of wild ducks from the north, mallards destroyed about \$35,000 worth of rice in the vicinity of De Witt and Stuttgart, Ark. Probably all the other grains found in the stomachs of the birds examined were put out as bait for the birds. This is not to say that mallards do not feed in grain fields, for they are well known to do so.

For instance, Kumlien and Hollister¹ state that large numbers of mallards wintering on the prairies of Wisconsin feed chiefly in the cornfields. In Manitoba² they are said to feed in wheat and barley stubble, rapidly becoming fat. It has been said that mallards at times are destructive to sprouting grain, but this is hardly true. Even if mallards did feed extensively upon sprouting grain, little if any harm would result, as they would only nip off the leaves, not dig up the grain.

SMARTWEEDS (9.83 PER CENT).

The seeds of smartweeds are produced abundantly in wet situations. Well filled with nutritious material, it is no wonder they are a favorite with wild ducks. The seeds of 13 species of smartweeds have been identified from stomachs of the mallard, besides buckwheat, *Brunnichia*, and dock, which belong to the same family. A mallard collected at a locality where buckwheat was used for bait had about 750 of the large akenes in its crop and gizzard. A smartweed with a prickly four-angled stem and arrow-shaped leaves (*Polygonum sagittatum*) is a favorite with mallards. Its seeds were identified in 107 stomachs, as many as 2,000 being found in one. No fewer than 4,500 seeds of the water pepper (*Polygonum hydropiper*) were taken from the crop and gizzard of another mallard.

PONDWEEDS (8.23 PER CENT).

The pondweed family is important to almost all ducks. These submerged plants are abundant and widespread, usually produce a good crop of seeds, and often have fleshy rootstocks and foliage which are wholly edible. Seeds of pondweeds, not further identified, were found in 431 mallard stomachs, up to 560 in number in a single instance. Remains of six species of the genus *Potamogeton* were found during the analyses. The most important species for the mallard as well as for other ducks is the sago pondweed (*Potamogeton pectinatus*), of which stems, foliage, seeds, rootstocks, and tubers all were eaten. Among other plants of this family, widgeon-grass (*Ruppia maritima*) was found in 72 gizzards and bushy pondweed (*Najas flexilis*) in 67. No fewer than 5,500 seeds of eelgrass (*Zostera marina*), a salt-water representative of the family, were found in a single mallard's stomach.

DUCKWEEDS (6.01 PER CENT) AND COONTAIL (5.97 PER CENT).

Duckweeds (*Lemnaceæ*) thickly cover the surface of the water in southern swamps, and coontail (*Ceratophyllum demersum*) fills the water beneath. Both contribute materially to the subsistence of

¹ Bull. Wisconsin Nat. Hist. Soc., III, Nos. 1-3, p. 17, 1903.

² Proc. U. S. Nat. Mus., XIII, 1890, p. 476.

mallards frequenting their home. The former were found in about 300 of the mallard stomachs examined, and there were thousands in some of them. Coontail was found in 669 stomachs. The leaves of the plant as well as the seeds are eaten. The largest number of seeds found in any one gizzard was 150.

WILD CELERY AND ITS ALLIES (4.26 PER CENT).

Wild celery (*Vallisneria spiralis*) is well known for its value as a wild-duck food. It is most important to the diving ducks, which are able to feed on the rootstocks and buds, but shoalwater ducks occasionally obtain these parts of the plant and in the proper season can feed at will on the leaves. Thirty-eight of the mallards examined had fed on wild celery and 135 upon the seeds of a related plant, frogbit (*Limnobium spongia*). Another plant of the same family, waterweed (*Philotria*), was found in small quantity in only two stomachs.

WAPATO AND ITS ALLIES (3.54 PER CENT).

Wapato belongs to the family of arrowheads, many of which have large and nutritious tubers. The mallard is not particularly adapted to get food requiring such strenuous digging, but nevertheless manages to obtain a share of the coveted tubers where they are abundant. From 6 to 8 tubers of the delta potato (*Sagittaria platyphylla*) were taken at a single meal by some of the birds, as were no fewer than 11 tubers of another species of *Sagittaria*. Tubers, stems, and seeds of *Sagittaria* were found in more than a hundred stomachs, and seeds of the related water plantain (*Alisma*) in three.

SEEDS OF TREES AND SHRUBS.

Where trees and shrubs bearing nutritious fruits are so situated that their products fall into the water, they sometimes become an important source of wild-duck food. Those most important to the mallard are trees of the elm and oak families. The water elm (*Planera aquatica*), a common tree of southern swamps, has large nutritious seeds which remain for months in a perfect state of preservation in the water into which they fall. There they are found and eagerly devoured by wild ducks. One hundred and fifty-nine of the mallards examined had fed upon these seeds, no fewer than 200 of them being taken by a single duck. The seeds of hackberry (*Celtis*), a tree also of the elm family, were found in 46 stomachs; and altogether seeds of plants of this family compose 4.11 per cent of the total food of the mallards examined.

The next largest item of mallard food produced by trees is acorns. These were found in 37 stomachs and form 2.34 per cent of the whole subsistence. Mallards sometimes resort in flocks to woods where

they can obtain acorns, and occasionally a bird takes so many that it is unable to fly. In connection with acorns it is appropriate to mention hickory nuts, contained in 96 mallard gizzards. These hard nuts might be thought beyond the powers of a duck to digest, but, on the contrary, they are taken care of with ease, being broken by the great pressure exerted by the gizzard as they are on the point of entering that organ. Once wholly within they quickly are ground to fine fragments.

Seeds of buttonbush (*Cephalanthus occidentalis*), a crooked, stiff-branched shrub of swamps, were taken from the gizzards of 428 mallards. Hundreds of them were present in some stomachs. They compose 1.76 per cent of the food. Buttonbush and the water elm find a congenial home in cypress swamps, and in these swamps tree-borne seeds, or mast, are an important element of duck food. The cypress itself contributes to this supply in two ways. The rounded cones or balls of the cypress after falling into the water separate into their constituent scales, which are of a size convenient for ducks to swallow. Such scales were found in 113 of the mallard stomachs examined. On the twigs and leaves of cypress grow a number of kinds of galls. These are deformations of the plant caused by the deposition of gallfly eggs and the subsequent feeding and growth of the larvæ. Some of those on cypresses are beautiful both in shape and color, simulating flowers. They were eaten by 60 of the ducks examined and together with cypress scales or seeds compose 1.33 per cent of the total diet.

Among other noteworthy articles of food derived from woody plants are grape seeds, found in 339 stomachs, those of redhaws in 184, poison ivy in 96, hollies in 80, the climbing bamboo vine, supple jack, or black jack in 60, dogwoods in 51, willow capsules in 32, *Styrax* in 30, bayberries in 35, swamp privet in 26, and tupelo or swamp gum in 24.

MISCELLANEOUS VEGETABLE FOOD.

Additional items of vegetable food that deserve special mention are the waterlilies, waterpennies, and heliotrope. Of the waterlilies, seeds of water shield (*Brasenia*) were found in 70 stomachs, and of the floating waterlilies (*Castalia*) in 27. All the waterlilies together constitute a little less than 1 per cent of the food. Seeds of waterpenny (*Hydrocotyle*) were taken from 226 gizzards and make up 1.39 per cent of the subsistence. Seeds of a heliotrope (*Heliotropium indicum*), a plant introduced from India, are a curious item found in a large number (104) of mallard stomachs. On the average, however, they form but a slight percentage of the food.

Other plant foods of interest and of some importance are algæ, including musk grass (*Chara*); seeds of pickerel weed (*Pontederia*

cordata); of thalia, a plant related to the cannas; of saltbush, water crowfoots, water milfoil, and mermaid weed; water hemlock; and of Spanish needle, or bur marigold.

ANIMAL FOOD.

The animal food of the mallard duck though extremely varied may be classed in five main groups: Insects, which constitute 2.67 per cent of the total diet; crustaceans, 0.35; mollusks, 5.73; fishes, 0.47; and miscellaneous, 0.25 per cent.

INSECTS (2.67 PER CENT).

The mallard's attentions to insects are divided about equally among beetles, bugs, and dragonflies, which together constitute 1.4 per cent of the total diet. All other insects make up 1.27 per cent. As would be expected, the beetles eaten are mostly denizens of the water. They include among others both larvæ and adults of the crawling water beetles (Haliplidæ), small spotted beetles, most often seen among algæ and other aquatic plants. Twenty different kinds of predacious diving beetles (Dytiscidæ) also were identified, both adults and larvæ being taken. The latter, so voracious that they have earned the name water tigers, are very destructive to other water-dwelling creatures and are a pest in fish ponds. Two partly predacious groups, the water scavenger beetles (Hydrophilidæ) and the whirligig beetles (Gyrinidæ) also are preyed upon by the mallard.

Among other beetles included in the dietary are ground beetles (Carabidæ), which are chiefly useful; and leaf beetles (Chrysomelidæ) and weevils, which are injurious. Of the leaf beetles, a group (*Donacia*) occurring in the mallard's habitat, and naturally fed upon, live upon waterlilies. The adults rest on lily pads or skip about on the water surface; the larvæ live in tough cocoons on the lily stems, from which they secure both food and oxygen. One of the weevils identified in the food is the rice water weevil, a pest to cultivated rice.

The bugs (Hemiptera) eaten by the mallard are practically all aquatic forms. They include water boatmen (Corixidæ), hundreds of which have been found in a single stomach; back-swimmers (Notonectidæ), water scorpions (Nepidæ), giant water bugs (Belostomatidæ), creeping water bugs (Naucoridæ), and water striders (Veliidæ and Gerridæ). All these bugs are predacious, but whether they do more good than harm is a question, as many of them prey upon small fishes. Besides the Hemiptera already mentioned, a variety of other bugs occasionally are devoured by the mallard.

Dragonflies, or snake-feeders, are active and expert insects on the wing, but in the younger stages they live in the water, where many of them fall a prey to the mallard. No fewer than 100 dragonfly nymphs have been found in one mallard's gizzard, and from 30 to 40

in others. Adult dragonflies were found in only one stomach. These insects prey upon mosquitoes, but their nymphs destroy young fish also, so that on the whole they are of no pronounced economic benefit.

Most of the other insects eaten by the mallard are more or less aquatic in habits. For instance, the flies (Diptera) eaten are chiefly those having aquatic larvæ, and it is the larvæ that are usually obtained. These include craneflies, mosquitoes, gnats, horseflies, soldierflies and flowerflies. Seven adult mosquitoes (*Culex restuans*) were found in one mallard's gizzard. Dr. Samuel G. Dixon, Health Commissioner of Pennsylvania, commends the mosquito-destroying capacity of the mallard. He writes: ¹

After trying the ability of fish to devour larvæ and pupæ of mosquitoes, with varied success, I built two dams near together on the same stream, so that each would have the same environment for the breeding of mosquitoes. Each covered nearly 1,400 square feet. In one twenty mallard ducks, *Anas platyrhyncha*, were permitted to feed, while the other was entirely protected from waterfowl, but well stocked with goldfish, *Carassius auratus*, variety *americanus*.

The one in which the ducks fed was for several months entirely free from mosquitoes, while the pond protected from ducks and stocked with fish was swarming with young insects in different cycles of life.

To the infested pond ten well-fed mallard ducks, *Anas platyrhyncha*, were then admitted, and as they entered the pond they were first attracted by the larval batrachians, tadpoles. They, however, soon recognized the presence of larvæ and pupæ of the mosquito and immediately turned their attention to these, ravenously devouring them in preference to any other foodstuff present. At the end of 24 hours no pupæ were to be found and in 48 hours only a few small larvæ survived. The motion of the water, made by the ducks, of course drowned some of the insects—what proportion can not be estimated.

For some years I have been using ducks to keep down mosquitoes in swamps that would have been very expensive to drain, but I never fully appreciated the high degree of efficiency of the duck as a destroyer of mosquito life until the foregoing test was made.

Mayflies, stoneflies, and caddisflies also are consumed, usually as larvæ. More than 200 caddisfly larvæ have been obtained from a single stomach. Caterpillars, including an aquatic form which lives in nests made of duckweed, occasionally are disclosed by stomach examination.

The other insects eaten include a few ants and other Hymenoptera, Orthoptera and their eggs, and bird lice (Mallophaga). The last-named undoubtedly are obtained from the bird's own body. That mallards at times feed extensively upon grasshoppers was observed particularly during outbreaks of the Rocky Mountain locust, when from 12 to 49 of these insects were found in various stomachs by Prof. Samuel Aughey.²

¹ Journ. Amer. Med. Assn., LXIII, no. 14, p. 1203, Oct. 3, 1914.

² First Ann. Rept. U. S. Ent. Comm., Appendix II, p. 58, 1877.

According to W. Stanley Hanson, of Fort Myers, Fla., mallards are effective enemies of another pest of this group, namely, the mole cricket. He says:

My flock of mallards have completely destroyed the mole crickets in my grounds. The ducks feed at night, when the little mole, so destructive in certain parts of Florida, is doing its work.

CRUSTACEANS (0.35 PER CENT).

Although a considerable variety of crustaceans are eaten by the mallard they do not form an important element of the diet. Crawfishes are of most interest among them on account of their destructive habits. They were eaten by 51 of the mallards examined, and from 4 to 6 specimens were found in some stomachs. Other crustaceans devoured by mallards include water fleas, sand fleas, sowbugs, fresh-water shrimps, and crabs.

MOLLUSKS (5.73 PER CENT).

Mollusks, the most important element of the animal food of the mallard, comprise three-fifths of this and 5.73 per cent of the total. Fresh-water snails are represented most numerous, no fewer than 50 sometimes being taken at a single meal. Small bivalves also are eaten and as many as 23 were found in a single stomach.

OTHER ANIMAL MATTER (0.72 PER CENT).

Among miscellaneous animal matter taken by the mallard, fishes, constituting a little less than half of 1 per cent of the total food, are most important. Remains of frogs were found in 19 stomachs. One record of especial interest relates to a duck collected in December, by J. A. Spurrell, at Wall Lake, Iowa. For two days before this was killed it had frequented a small patch of open water in a creek, caused by the water from a drain. The bird had eaten two crawfishes and two or more frogs, which it must have secured from the muddy bottom to which such animals retreat during the winter.

Other animals found in mallard stomachs were nematode worms, including the so-called hairworms; fresh-water bryozoans, marine worms, earthworms, water mites, and spiders.

Besides the foregoing items of animal food, the following are stated by various writers to contribute occasionally to the food of the mallard: Barnacles, leeches, snakes, mice, salmon eggs, and carrion, including dead salmon and other fishes.

BLACK DUCK.

(*Anas rubripes*.)

The black duck is a close relative of the mallard. In size and form the two species are practically identical, and in both the female has the same loud resonant quack that distinguishes the mallards

from all other ducks. The black duck differs radically from the mallard in coloration, however, and also is different from that species in having the sexes colored alike. In temperament, furthermore, the black duck varies considerably from its more abundant relative. It is wilder, seldom lapsing from an attitude of intense wariness; it appears keener in every way, and its senses of sight, hearing, and smell are constantly alert. It is, therefore, a gamier species than the mallard, and for the same reasons is not so susceptible to domestication. It is also distinctly more nocturnal in habit than the mallard.

Vernacular names for the species, other than the one commonly used, include dusky duck, black mallard, black stock duck, and canard noir.

Breeding from Virginia and Iowa north to Hudson Bay and Labrador, the black duck ranges in winter from Nova Scotia south to Florida and Louisiana, and casually to Colorado.¹ It is not distributed uniformly over this region, however, and the probabilities are that a large majority of the individuals winter in the Atlantic Coast States from New England to the Carolinas.

FOOD HABITS.

Unevenness in distribution results in the black duck's feeding more extensively than the mallard in salt marshes and other areas characteristic of the coast region. In such places animal food, as mollusks and crustaceans, is abundant and contributes more to the subsistence of ducks than is the case in inland waters. Accordingly, the black duck consumes almost three times as much animal food as the mallard. The actual percentages, contrasted, are, respectively, 24.09 and 9.47. Due to its habit of frequenting salt water, the black duck also devours far more eelgrass (*Zostera marina*) than the mallard. The total percentage of vegetable food is 75.91.

The number of black duck stomachs examined was 622. In tabulating the results 232 stomachs were excluded, as they were either nearly empty or were taken in poorly represented months. The statements as to percentages of food, therefore, are based on the contents of 390 stomachs collected in the six months from September to February. This material was obtained in 19 States and in 2 Canadian Provinces. The distribution both geographically and through the months is very satisfactory.

VEGETABLE FOOD.

Three-fourths (75.91 per cent) of the food of the black ducks examined consisted of vegetable matter, and fully half of this was derived from such submerged plants as the pondweeds, eelgrass, and

¹ Opinion is now almost unanimous that there are two forms of the black duck, a red-legged bird (*Anas rubripes rubripes*), occupying the whole northern and interior range of the species; and a dark-legged race (*A. r. tristis*), occurring along the Atlantic coast up to the Gulf of St. Lawrence.

wild celery. The pondweed group alone, including the ordinary pondweeds (*Potamogeton*), bushy pondweed (*Najas*), widgeon-grass (*Ruppia*), horned pondweed (*Zannichellia*), and eelgrass (*Zostera*), composed 32.34 per cent of the total diet. Leaves, stems, tubers, winter buds, and seeds of pondweeds are eaten, and 700 seeds were found in a single stomach. No fewer than 4,000 seeds of eelgrass were taken from the gizzard and gullet of one black duck. Wild celery is an important food plant, but as it was not tabulated separately, its percentage can not be stated.

Following the pondweed group in importance are the grasses and sedges, each contributing nearly 11 per cent to the diet of the black mallard. The most important grasses are salt-marsh grass (*Spartina*) and wild rice (*Zizania*). Some stomachs contained from 1,000 to 1,200 grains of wild rice. Cultivated rice was found in two gizzards, to the extent of 720 kernels in one. It was gleaned from fields already harvested. A notable part of the total percentage of grasses was made up of corn supplied to the ducks as bait. One bird had taken 227 kernels at a meal. Wheat, also used as a bait, was found in one stomach.

The sedges which supply most food to black ducks are the bulrushes (*Scirpus*). Mainly the seeds of these plants are devoured, and 2,000 have been found in one stomach. The tubers, as a rule, are sparingly eaten, but one species (*Scirpus pauciflorus*), common about the southern end of Hudson Bay, has a tender propagating bud which is eagerly eaten by ducks, and of which the black duck takes its share. Of other sedges, the following total numbers of seeds were taken from single stomachs: *Carex*, 320; twig rush (*Cladium*), 720; and *Fimbristylis*, 900. The stems, leaves, and rootstocks of sedges also are eaten occasionally.

Smartweeds are important to the black duck as also they are to many other wild fowl. Their seeds make up a twentieth of the food of this bird, and nine different species were identified; from 2,000 to 3,200 were found in individual stomachs, and in one the enormous total of 36,300.

Seeds of bur-reeds (*Sparganium*), usually not a conspicuous element of wild-duck food, were found in 144 stomachs of black ducks, to the number of 200 to 250 in several. They make up 3.37 per cent of the diet. Algæ form a larger element of the food of the black duck than of most of its relatives. This is merely because the maritime habits of the bird give it access to seaweeds. Musk grasses (*Chara*), a fresh-water group, also were among the algæ eaten.

Other items of vegetable food worthy of mention are the seeds of water shield (*Brasenia*), waterlilies, and coontail (*Ceratophyllum*), which together form 1.36 per cent of the food; leaves, roots, and tubers of various wapatos; seeds of pickerel weed, and of grape and

mermaid weed. Items of especial interest, although of less importance, are huckleberries, of which more than 800 seeds were found in one stomach and 200 in another; seeds of a wake-robin, or trillium, of which one bird had devoured 523; of sea purslane, reaching a total of 800 in the single instance found; and of common ragweed, 900 of which had been consumed at a single meal. Seeds said by Nuttall to be taken by the black duck additional to the vegetable food revealed by these stomach examinations are of a bog plant, *Scheuchzeria palustris*.

ANIMAL FOOD.

As usual, the animal food consists of a larger number of different items than the vegetable, although individually these are of very much less importance than the plants. In all, they compose 24.09 per cent of the total. A little over half of this, namely, 12.27 per cent, is made up of mollusks or shellfish. Both bivalve and univalve shells are eaten, but many more of the latter, in accordance with their greater abundance. Of the bivalves, the common blue mussel (*Mytilus edulis*) is most important. It was found in 35 stomachs, and to the number of 30 in a single instance. This shellfish is enormously abundant, and although used to some extent for food and fish bait, can not be said to have a value that renders the birds feeding upon it economically injurious.

Univalves were taken in all stages, including eggs. No fewer than 650 snails were found in one stomach and of univalves and bivalves together 1,200 were present in a single case. Shells of the genus *Litorina* are frequently taken, and five species were identified. A common introduced form, *L. rudis*, was found in 38 gizzards, in one to the number of 150 individuals.

Crustacea, including barnacles, sand fleas, water fleas, sowbugs, shrimps, crawfishes, and crabs, are next in importance to Mollusca in the animal food of the black duck. They compose 7.99 per cent of the total diet. Hundreds of the smaller kinds were present in some stomachs, as were also as many as 60 sowbugs and 30 crabs. In a single instance a specimen of the common edible crab (*Callinectes sapidus*) was identified.

The other items of the animal food that form noteworthy percentages are insects and fishes. The insects taken are largely aquatic beetles and bugs, but dragonflies, especially in their immature stages, earwigs, crickets, grasshoppers, caddisflies and their larvæ, two-winged flies, and ants also are taken. The rice water weevil was among the beetles eaten, 20 being found in one stomach. In all, insects amount to 1.89 per cent of the food. Fishes and their eggs were found in 20 stomachs and compose 1.34 per cent of the subsist-

ence. An eel and some killifishes (*Fundulus*), neither of particular food value, were identified, and the fish eggs eaten probably also were those of killifishes. Another item of animal food worthy of mention is marine worms of the genus *Nereis*. These were found in 17 stomachs, no fewer than 25 in one. These worms prey to some extent upon oysters and other shellfish.

Elements of the animal food of the black duck credibly reported by other observers ¹ but not found during the present investigation are: angle-worms, the sand flea *Gammarus ornatus*, the isopod *Idotea marina*, and the snail *Campeloma decisa*.

FOOD OF THE YOUNG.

Having gizzards from representatives of three different broods of black ducks allows brief discussion of the food habits of the young. As is the case with a majority of birds, the percentage of animal food taken by the young is much higher than by the adults. For the three broods examined it ranges from 40 to 79.25 per cent. The constituents of this part of the food are practically the same as those taken by adults with the exception of fish eggs. All of a 6-day-old brood of five black mallards taken on Wallops Island, Va., May 18, 1910, had eaten eggs of fishes, probably of the little killifishes so abundant in salt marshes. The food of a brood from James Bay, Canada, taken July 13, 1914, consisted on the average of 96 per cent caddis larvæ. The vegetable food of the young showed no peculiarities, except that possibly more odds and ends, rare items in the dietary, were picked up than would be by an equal number of adults. Such were seeds of marsh mallow (*Hibiscus*), cleavers (*Galium*), *Hypericum*, lamb's-quarters (*Chenopodium*), amaranth, *Lippia modiflora*, and rose. The Wallops Island brood mentioned made on the average 47 per cent of its food of algæ.

SOUTHERN BLACK DUCK.

(*Anas fulvigula*.)

The southern black duck inhabits peninsular Florida and a narrow strip of marsh and swamp land bordering the Gulf of Mexico from Florida to Texas. Usually it is considered to consist of two subspecies, the Florida duck (*Anas fulvigula fulvigula*), and the mottled duck (*A. f. maculosa*), the latter living in Louisiana and Texas. However, these are treated together here as the southern black duck. This is a smaller and lighter-colored bird than its northern relative and may be recognized by the plain creamy buff throat and foreneck. In the northern black duck these parts are streaked with dusky.

¹ This does not include the generalization of Audubon.

Besides the vernacular names already mentioned, the following are applied to this species: Summer duck, summer French duck, canard noir d'été, canard des isles, and Mexican mallard. In general, the habits of this species are much like those of the northern black mallard.

FOOD HABITS.

The fact that the black duck takes a notably larger proportion of animal food than the common mallard probably is due, as has been noted, simply to greater availability of this class of food to the black duck, as that species spends more time in coastal marshes, where animal food is more abundant and accessible through a longer season. The southern black duck, living in an area where cold weather is experienced only occasionally and for only short periods, has a better opportunity to get animal food than the black duck. It responds to this superior availability, which after all is the guiding principle in the choice of food by birds, by making 40.5 per cent of its diet of animal matter. This exceeds the proportion taken by the black duck by approximately 15 per cent, almost the same difference as between that species and the mallard.

Fifty-one stomachs of the southern black duck have been examined and analyses of 48 of them were used for the percentages. Although this is a rather small representation of the species, the stomachs are distributed fairly well through the six months from November to April and represent all the usual haunts of the species—the Everglades and the river marshes of Florida, the coast marshes of Louisiana, and the coastal lakes and lagoons of Texas. It is probable, therefore, that they afford a reasonably accurate idea of the feeding habits of this species.

VEGETABLE FOOD.

Grasses are the most important element of the vegetable food of the southern black duck, forming almost half of it. Frequently the rootstocks are dug up and devoured, and some stems and leaves are eaten. Of the grass seeds consumed, cultivated rice is most important. Most of that found in the stomachs was waste, being taken in winter, and as it included red rice, some good was done by eating it. However, as the southern black duck spends the summer in the country where much rice is grown, it has the opportunity of feeding upon the crop in the younger and more appetizing stages. It is said to do this sometimes to a destructive extent. However, the game value of the duck makes it undesirable to take aggressive measures against it on behalf of the rice crop. A toll large enough, if not too large, is taken of the birds during the hunting season.

Next to grasses the seeds of smartweeds are preferred. They form almost a tenth (9.54 per cent) of the total diet. No fewer than 800

seeds of prickly smartweed (*Polygonum sagittatum*) were taken from a single stomach. The seeds and tubers of sedges compose the next largest item, namely, 6.34 per cent. Seeds of waterlilies and coontail make up 3.11 per cent and seeds, stems, and foliage of pondweeds and widgeon-grass, 1.6 per cent. Other items of vegetable food worth mentioning are bayberries and seeds of buttonbush.

ANIMAL FOOD.

As is true of both of its close relatives, the southern black duck consumes more mollusks than any other kind of animal food. These shellfish compose five-eighths of the animal diet and nearly 27 per cent of the whole food. Snails as large as one inch in diameter were among those eaten. Insects, making up less than a third as much of the food, are next in importance. Dragonfly nymphs, rarely adults, water bugs, caddis larvæ, a variety of beetles, and flies, including horsefly larvæ, are the principal items taken. Crustacea, chiefly crawfishes, contribute 2.77 per cent of the food, and fishes, no doubt small worthless kinds, 2.57 per cent.

TABLE I.—*Items of vegetable food identified in stomachs of mallard ducks and the number in which found.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
SUBKINGDOM EUTHALLOPHYTA.			
Unidentified algæ.....	21	31	
<i>Chara</i> sp. (musk grass).....	29	2	
<i>Fucus</i> sp. (seaweed).....		3	
SUBKINGDOM BRYOPHYTA.			
<i>Ricciella</i> sp. (floating liverwort).....	4		
Moss.....	1		
SUBKINGDOM PTERIDOPHYTA.			
Marsileaceæ.			
<i>Marsilea vestita</i> (pepperwort).....	3		
<i>Marsilea</i> sp. (pepperwort).....	2		
Equisetaceæ.			
<i>Equisetum</i> sp. (horsetail).....	1		
SUBKINGDOM SPERMATOPHYTA.			
Pinaceæ.			
<i>Pinus taeda</i> (loblolly pine).....	2		
<i>Pinus</i> sp. (pine), needles.....		2	
<i>Picea</i> sp. (spruce), needles.....	1	1	
<i>Taxodium distichum</i> (bald cypress).....	113	1	
<i>Taxodium distichum</i> (bald cypress), galls.....	60		
Sparganiaceæ.			
<i>Sparganium androcladum</i> (bur reed).....	6	3	
<i>Sparganium eurycarpum</i> (bur reed).....	25	2	
<i>Sparganium</i> sp. (bur reed).....	116	139	

TABLE I.—Items of vegetable food identified in stomachs of mallard ducks and the number in which found—Continued.

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
SUBKINGDOM SPERMATOPHYTA—Continued.			
Potamogetonaceæ.			
<i>Potamogeton lucens</i> (shining pondweed).....	3	.....	.....
<i>Potamogeton praelongus</i> (white-stemmed pondweed).....	1	.....	.....
<i>Potamogeton foliosus</i> (leafy pondweed).....	2	2	.....
<i>Potamogeton friesii</i> (Fries pondweed).....	4	.....	.....
<i>Potamogeton pusillus</i> (small pondweed).....	5	.....	.....
<i>Potamogeton pectinatus</i> (sago pondweed).....	43	19	1
<i>Potamogeton perfoliatus</i> (redhead grass).....	.....	1	.....
<i>Potamogeton</i> sp. (unidentified pondweed).....	431	217	.....
<i>Ruppia maritima</i> (widgeon-grass).....	85	101	4
<i>Zannichellia palustris</i> (horned pondweed).....	10	2	.....
<i>Zostera marina</i> (eelgrass).....	4	71	.....
Naiadaceæ.			
<i>Najas flexilis</i> (bushy pondweed).....	75	32	1
Juncaginaceæ.			
<i>Triglochin maritima</i> (arrow-grass).....	7	.....	.....
Alismaceæ.			
<i>Echinodorus</i> sp. (burhead).....	1	.....	.....
<i>Alisma plantago-aquatica</i> (water plantain).....	3	.....	.....
<i>Alisma</i> sp. (water plantain).....	3	.....	.....
<i>Sagittaria platyphylla</i> (delta potato).....	89	.....	.....
<i>Sagittaria latifolia</i> (wapato).....	2	3	.....
<i>Sagittaria teres</i> (goose-grass).....	.....	1	.....
<i>Sagittaria graminea</i> ? (grass-leaved wapato).....	.....	7	.....
<i>Sagittaria</i> sp. (arrowhead).....	23	1	.....
<i>Damasonium californicum</i>	2	.....	.....
Hydrocharitaceæ.			
<i>Philotria canadensis</i> (waterweed).....	2	.....	.....
<i>Vallisneria spiralis</i> (wild celery).....	38	23	.....
<i>Limnobium spongia</i> (frogbit).....	135	.....	.....
Gramineæ.			
Unidentified grasses.....	74	6	.....
<i>Zea mays</i> (Indian corn).....	14	7	.....
<i>Sorghum</i> sp.....	.....	1	.....
<i>Paspalum distichum</i> ¹	1	.....	.....
<i>Paspalum</i> sp.....	8	.....	.....
<i>Echinochloa crus-galli</i> (wild millet).....	69	4	2
<i>Panicum</i> sp. (switch grass).....	68	13	2
<i>Panicum dichotomiflorum</i> (switch grass).....	1	.....	.....
<i>Chaetochloa lutescens</i> (yellow foxtail).....	2	.....	.....
<i>Chaetochloa</i> sp. (foxtail grass).....	8	1	1
<i>Cenchrus</i> sp. (burgrass).....	1	.....	.....
<i>Zizaniopsis miliacea</i> (cut grass).....	41	2	.....
<i>Zizania aquatica</i> (wild rice).....	91	29	.....
<i>Homalocenchrus oryzoides</i> (rice cut grass).....	6	.....	.....
<i>Homalocenchrus lenticularis</i> (catch-fly grass).....	2	.....	.....
<i>Homalocenchrus virginicus</i> (false rice).....	4	.....	.....
<i>Homalocenchrus</i> sp. (unidentified cut grass).....	13	1	1

¹ *Paspalum boscianum* and *Eriochloa punctata* also have been identified from a common mallard's stomach by L. H. Dewey.

TABLE I.—*Items of vegetable food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
SUBKINGDOM SPERMATOPHYTA —Continued.			
Gramineæ—Continued.			
<i>Oryza sativa</i> (cultivated rice).....	60	2	7
<i>Avena sativa</i> (cultivated oats).....	3		
<i>Danthonia</i> sp. (oat grass).....	1		
<i>Spartina</i> sp. (salt-marsh grass).....	20	62	
<i>Leptochloa floribunda</i> (feather grass).....	1		
<i>Eragrostis</i> sp. (love grass).....	5		
<i>Monanthochloë littoralis</i>	7	5	1
<i>Distichlis spicata</i> (salt grass).....	4		
<i>Panicularia nervata</i> (meadow grass).....	12		
<i>Poa</i> sp. (meadow grass).....		1	
<i>Festuca brachyphylla</i> (fescue grass).....		1	
<i>Bromus</i> sp. (brome grass).....	1		
<i>Hordeum sativum</i> (barley).....	7		
<i>Hordeum murinum</i> (wild barley).....	1		
<i>Triticum æstivum</i> (wheat).....	1	1	
Cyperaceæ.			
Unidentified sedges.....	114	23	
<i>Cyperus esculentus</i> (chufa).....	1	1	2
<i>Cyperus ferax</i> (chufa).....	10		
<i>Cyperus</i> sp. (chufa).....	48	5	1
<i>Scirpus paludosus</i> (prairie bulrush).....	9		
<i>Scirpus fluviatilis</i> (river bulrush).....	45	4	
<i>Scirpus cubensis</i> (bulrush).....	286		
<i>Scirpus americanus</i> (three-square).....	22		
<i>Scirpus pauciflorus</i> (club-rush).....		3	
<i>Scirpus</i> sp. (unidentified bulrush).....	540	194	6
<i>Eleocharis</i> sp. (spike-rush).....	37	36	
<i>Fimbristylis</i> sp. (sedge).....	279	25	3
<i>Psilocarya nitens</i> (bald rush).....	3		
<i>Psilocarya</i> sp. (bald rush).....	10		
<i>Cladium effusum</i> (saw grass).....	239	8	16
<i>Cladium mariscoides</i> (twig rush).....	7	27	
<i>Rhynchospora corniculata</i> (pollywog).....	24	2	7
<i>Rhynchospora</i> sp. (beaked rush).....	5		3
<i>Dichromena</i> sp.....	6		
<i>Scleria reticularis</i> (nut rush).....			1
<i>Scleria torreyana</i> (nut rush).....			1
<i>Scleria</i> sp. (nut rush).....	13		3
<i>Carex decomposita</i> (panicled sedge).....	77		
<i>Carex lupulina</i> (hop sedge).....	1		
<i>Carex lupuliformis</i> (hop sedge).....	7		
<i>Carex gigantea</i> (hop sedge).....	12		
<i>Carex</i> sp. (sedge).....	28	50	
Araceæ.			
<i>Peltandra virginica</i> (hog wampee).....			1
Lemnaceæ.			
<i>Lemna minor</i> (small duckweed).....	10		
<i>Lemna trisulca</i> (star duckweed).....	1		
<i>Lemna</i> sp. (unidentified duckweeds).....	247	4	

TABLE I.—Items of vegetable food identified in stomachs of mallard ducks and the number in which found—Continued.

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
SUBKINGDOM SPERMATOPHYTA —Continued.			
Lemnaceæ—Continued.			
<i>Spirodela polyrhiza</i> (greater duckweed).....	2	.....	.....
<i>Wolffia columbiana</i> (water meal).....	3	.....	.....
<i>Wolffia</i> sp. (water meal).....	65	1	.....
Eriocaulaceæ.			
<i>Eriocaulon</i> sp. (pipewort).....	.....	1	.....
Xyridaceæ.			
<i>Xyris</i> sp. (yellow-eyed grass).....	1	.....	.....
Commelinaceæ.			
<i>Commelina</i> sp. (dayflower).....	1	1	.....
Pontederiaceæ.			
<i>Pontederia cordata</i> (pickerel weed).....	31	11	2
Liliaceæ.			
Unidentified.....	2	.....	.....
Convallariaceæ.			
<i>Vagnera</i> sp. (false Solomon's seal).....	.....	1	.....
Trilliaceæ.			
<i>Trillium</i> sp.....	.....	1	.....
Smilacæ.			
<i>Smilax</i> sp. (greenbriar).....	6	2	2
Marantaceæ.			
<i>Thalia divaricata</i>	2	.....	.....
Juglandaceæ.			
<i>Hicoria aquatica</i> (bitter pecan).....	7	.....	.....
<i>Hicoria</i> sp. (hickory).....	89	2	.....
Myricaceæ.			
<i>Myrica cerifera</i> (bayberry).....	5	.....	16
<i>Myrica carolinensis</i> (bayberry).....	1	.....	.....
<i>Myrica</i> sp. (bayberry).....	29	60	.....
Salicaceæ.			
<i>Salix</i> sp. (willow), leaves and capsules.....	32	1	.....
Betulaceæ.			
<i>Carpinus caroliniana</i> (hornbeam).....	3	.....	.....
<i>Betula</i> sp. (birch).....	1	.....	.....
Fagaceæ.			
<i>Quercus alba</i> (white oak).....	1	.....	.....
<i>Quercus lyrata</i> (overcup oak).....	1	.....	.....
<i>Quercus</i> sp. (unidentified oaks).....	35	1	.....
Ulmaceæ.			
<i>Planera aquatica</i> (water elm).....	159	1	.....
<i>Celtis mississippiensis</i> (hackberry).....	3	.....	.....
<i>Celtis</i> sp. (hackberry).....	43	.....	.....
Polygonaceæ.			
<i>Rumex persicarioides</i> (golden dock).....	1	.....	.....
<i>Rumex</i> sp. (dock).....	10	2	.....
<i>Polygonum amphibium</i> (water smartweed).....	117	2	1
<i>Polygonum arifolium</i> (prickly smartweed).....	8	4	.....
<i>Polygonum aviculare</i> (knotweed).....	13	.....	.....
<i>Polygonum convolvulus</i> (climbing buckwheat).....	3	.....	.....
<i>Polygonum dumetorum</i> (climbing buckwheat).....	1	.....	.....
<i>Polygonum hydropiper</i> (water pepper).....	137	11	.....

TABLE I.—Items of vegetable food identified in stomachs of mallard ducks and the number in which found—Continued.

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
SUBKINGDOM SPERMATOPHYTA—Continued.			
Polygonaceæ—Continued.			
<i>Polygonum hydropiperoides</i> (water pepper).....	2		
<i>Polygonum lapathifolium</i> (smartweed).....	5	2	
<i>Polygonum opelousanum</i> (smartweed).....	53	2	
<i>Polygonum pennsylvanicum</i> (smartweed).....	8	3	
<i>Polygonum persicaria</i> (smartweed).....	10	3	
<i>Polygonum punctatum</i> (smartweed).....	2	2	
<i>Polygonum sagittatum</i> (prickly smartweed).....	407	47	16
<i>Polygonum</i> sp. (unidentified smartweeds).....	191	45	1
<i>Fagopyrum esculentum</i> (buckwheat).....	5		
<i>Brunnichia cirrhosa</i>	4		
Amaranthaceæ.			
<i>Amaranthus</i> sp. (tumbleweed).....	4	3	
Chenopodiaceæ.			
<i>Chenopodium album</i> (lamb's-quarters).....	2		
<i>Chenopodium</i> sp. (lamb's-quarters).....	6	1	
<i>Salsola kali</i> (saltwort).....	1	2	
<i>Atriplex</i> sp. (saltbush).....	1		
<i>Salicornia ambigua</i> (pickle grass).....	4		
<i>Salicornia</i> sp. (pickle grass).....		5	
Phytolaccaceæ.			
<i>Phytolacca americana</i> (pokeweed).....	4		
<i>Rivina humilis</i>	2		
Portulacaceæ.			
<i>Portulaca oleracea</i> (purslane).....	1		
Aizoaceæ.			
<i>Sesuvium maritimum</i> (sea purslane).....		1	
Caryophyllaceæ.			
Unidentified chickweed.....	1		
<i>Arenaria</i> sp. (sandwort).....		2	
Ranunculaceæ.			
<i>Batrachium trichophyllum</i> (white water-crowfoot).....	1		
<i>Batrachium</i> sp. (white water-crowfoot).....	8		
<i>Ranunculus delphinifolius</i> (yellow water-crowfoot).....	10		
<i>Ranunculus missouriensis</i> (yellow water-crowfoot).....	8		
<i>Ranunculus</i> sp. (crowfoot).....	28		
Ceratophyllaceæ.			
<i>Ceratophyllum demersum</i> (coontail).....	669	12	1
Cabombaceæ.			
<i>Brasenia schreberi</i> (water shield).....	70	33	1
<i>Cubomba caroliniana</i> (Carolina water shield).....	1		
Nymphæaceæ.			
<i>Nymphæa advena</i> (spatterdock).....	3		
<i>Nymphæa americana</i> (spatterdock).....		1	
<i>Nymphæa polysepala</i> (spatterdock).....	5		
<i>Nymphæa</i> sp. (spatterdock).....	8	1	6
<i>Castalia mexicana</i> (banana waterlily).....	13		1
<i>Castalia</i> sp. (waterlily).....	14	2	2
Unidentified waterlilies.....	8		
Papaveraceæ.			
<i>Papaver</i> sp. (poppy).....	1		

TABLE I.—Items of vegetable food identified in stomachs of mallard ducks and the number in which found—Continued.

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
SUBKINGDOM SPERMATOPHYTA —Continued.			
Capparidaceæ.			
<i>Cleome serrulata</i> (three-leaved spider flower).....	1		
Altingiaceæ.			
<i>Liquidambar styraciflua</i> (sweet gum).....	19		
Platanaceæ.			
<i>Platanus occidentalis</i> (sycamore).....	3		
Rosaceæ.			
<i>Rosa</i> sp. (rose).....	3	2	
<i>Rubus</i> sp. (blackberry).....	8	10	
Malaceæ.			
<i>Cratægus</i> sp. (red haw).....	184	3	
Amygdalaceæ.			
<i>Prunus virginiana</i> (chokecherry).....		3	
<i>Prunus</i> sp. (cherry).....		11	
Cæsalpinaceæ.			
<i>Cassia</i> sp. (senna).....	1		1
Fabaceæ.			
<i>Trifolium</i> sp. (clover).....	13		
<i>Medicago denticulata</i> (bur clover).....	2		
<i>Lespedeza</i> sp. (bush clover).....	1		
<i>Lespedeza striata</i> (Japan clover).....	1		
<i>Strophostyles</i> sp. (wild bean).....	1		
<i>Pisum sativum</i> (cultivated pea).....		1	
Unidentified.....	1		
Geraniaceæ.			
<i>Geranium longipes</i>	2		
<i>Geranium</i> sp.....	2		
Rutaceæ.			
<i>Citrus sinensis</i> (cultivated orange).....		1	
Euphorbiaceæ.			
<i>Croton</i> sp. (spurge).....	37		
<i>Euphorbia</i> sp. (spurge).....	1		
Callitrichaceæ.			
<i>Callitriche</i> sp. (water starwort).....		1	
Empetraceæ.			
<i>Empetrum nigrum</i> (crowberry).....		3	
Anacardiaceæ.			
<i>Rhus glabra</i> (smooth sumac).....	2	4	
<i>Rhus toxicodendron</i> (poison ivy).....	96	1	
<i>Rhus</i> sp. (unidentified sumac).....	4	5	1
Aquifoliaceæ.			
<i>Ilex vomitoria</i> (youpon).....	1		
<i>Ilex decidua</i> (swamp holly).....	1		
<i>Ilex verticillata</i> (black alder).....	1	4	
<i>Ilex</i> sp. (holly).....	77	5	1
Sapindaceæ.			
<i>Cardiospermum halicababum</i> (balloon vine).....	7		
Balsaminaceæ.			
<i>Impatiens biflora</i> (touch-me-not).....		1	
Vitaceæ.			
<i>Vitis</i> sp. (grape).....	339	8	1

TABLE I.—*Items of vegetable food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined	1,725	622	51
SUBKINGDOM SPERMATOPHYTA —Continued.			
Malvaceæ.			
<i>Malva</i> sp. (mallow)	2		
<i>Sida</i> sp. (nail grass)	6		
<i>Hibiscus moscheutos</i> (rose mallow)		1	
<i>Hibiscus</i> sp. (marsh mallow)	4	4	
Unidentified	2		
Hypericaceæ.			
<i>Hypericum</i> sp.		1	
Passifloraceæ.			
<i>Passiflora incarnata</i> (passion flower)	1		
Cactaceæ:			
<i>Opuntia</i> sp. (prickly pear)	1		
Lythraceæ:			
<i>Decodon verticillatus</i> (willow herb)	15	1	
Onagraceæ:			
<i>Jussiaea leptocarpa</i> (primrose willow)	2		
<i>Jussiaea</i> sp. (primrose willow)	3		
Haloragidaceæ:			
<i>Hippuris vulgaris</i> (bottle brush)	47	1	
<i>Proserpinaca pectinata</i> (mermaid weed)	4		
<i>Proserpinaca</i> sp. (mermaid weed)	52	10	3
<i>Myriophyllum heterophyllum</i> (water milfoil)	2		
<i>Myriophyllum</i> sp. (water milfoil)	86	3	
Ammiaceæ:			
<i>Hydrocotyle</i> sp. (waterpenny)	226	3	
<i>Centella asiatica</i> (waterpenny)	4		1
<i>Apium graveolens</i> (celery)	2		
<i>Cicuta</i> sp. (water hemlock)	24		
Unidentified	1		
Cornaceæ:			
<i>Cornus florida</i> (flowering dogwood)	1		
<i>Cornus nuttallii</i> (flowering dogwood)	1		
<i>Cornus alternifolia</i> (dogwood)	1		
<i>Cornus asperifolia</i> (dogwood)	28		
<i>Cornus occidentalis</i> (dogwood)	2		
<i>Cornus stolonifera</i> (dogwood)	1	1	
<i>Cornus</i> sp. (dogwood)	17	2	
<i>Berchemia vulubilis</i> (blackjack)	60		
<i>Nyssa aquatica</i> (tupelo)	22		
<i>Nyssa sylvatica</i> (sour gum)	17	2	
<i>Nyssa</i> sp. (tupelo)	2		
Fricaceæ:			
<i>Ledum</i> sp. (Labrador tea)	1		
<i>Arctostaphylos</i> sp. (kinnikinnik)	1		
Vacciniaceæ:			
<i>Gaylussacia baccata</i> (huckleberry)		2	
<i>Gaylussacia</i> sp. (huckleberry)		1	
<i>Vaccinium</i> sp. (blueberry)		1	
Primulaceæ:			
<i>Anagallis arvensis</i> (pimpernel)	2		
Ebenaceæ:			
<i>Diospyros virginiana</i> (persimmon)	1		

TABLE I.—*Items of vegetable food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
SUBKINGDOM SPERMATOPHYTA —Continued.			
Styracaceæ:			
<i>Styrax americana</i> (smooth storax).....	1		
<i>Styrax pulverulenta</i> (downy storax).....	1		
<i>Styrax</i> sp. (storax).....	28		
Oleaceæ:			
<i>Frazinus</i> sp. (ash).....	4		
<i>Adelia acuminata</i> (swamp privet).....	26		
Menyanthaceæ:			
<i>Menyanthes trifoliata</i> (bog bean).....	6	4	
Asclepiadaceæ:			
<i>Asclepias</i> sp. (milkweed).....	1		
Convolvulaceæ:			
<i>Ipomœa</i> sp. (morning-glory).....	6		
Unidentified.....	12		
Cuscutaceæ:			
<i>Cuscuta</i> sp. (dodder).....	19	4	2
Boraginaceæ:			
<i>Heliotropium indicum</i> (heliotrope).....	104		3
<i>Heliotropium</i> sp. (heliotrope).....	2		
Verbenaceæ:			
<i>Verbena</i> sp.....	2		
<i>Lippia nodiflora</i>		1	
<i>Lippia</i> sp.....	1		
Plantaginaceæ:			
<i>Plantago rugelii</i> (plantain).....	1		
Rubiaceæ:			
<i>Cephalanthus occidentalis</i> (buttonbush).....	428	8	7
<i>Diodia virginiana</i> (buttonweed).....	11		
<i>Diodia teres</i> (buttonweed).....	25		
<i>Diodia</i> sp. (buttonweed).....	2		
<i>Galium</i> sp. (cleavers).....	10	5	
<i>Psychotria tenuifolia</i>	1		
Caprifoliaceæ:			
<i>Triosteum perfoliatum</i> (feverwort).....	1		
<i>Symphoricarpos racemosus</i> (snow berry).....	2		
<i>Symphoricarpos</i> sp. (snow berry).....	1		
Ambrosiaceæ:			
<i>Ambrosia elatior</i> (ragweed).....	2	1	
<i>Ambrosia trifida</i> (ragweed).....	4		
<i>Ambrosia</i> sp. (ragweed).....	5		
Compositæ:			
<i>Eupatorium</i> sp.....	1		
<i>Helianthus</i> sp. (sunflower).....	1		
<i>Bidens bidentoides</i> (Spanish needles).....	1		
<i>Bidens cernua</i> (bur marigold).....	1		
<i>Bidens frondosa</i> (Spanish needles).....	1		
<i>Bidens</i> sp. (Spanish needles).....	47	1	
<i>Carduus</i> sp. (thistle).....	6	2	
Unidentified.....	2		

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined	1,725	622	51
SUBKINGDOM CŒLEENTERATA.			
Alcyonaria (sea fans)		3	
Hydrozoa (hydroid)	1		
SUBKINGDOM NEMATHELMINTHES.			
Gordiidae (hairworm)	1		
SUBKINGDOM MOLLUSCOIDA.			
Phylactolaemata (fresh-water bryozoa)	12		
SUBKINGDOM ECHINODERMATA.			
Echinoidea (sea urchin)		2	
SUBKINGDOM ANNULATA.			
Unidentified annelid	1		
Lumbricomorpha (earthworm)	1		
<i>Nereis</i> sp. (marine worm)	2	17	
SUBKINGDOM ARTHROPODA.			
CLASS Crustacea (CRUSTACEANS).			
Unidentified	3	15	
Order OSTRACODA.			
Bivalved crustacean, unidentified	2		
<i>Candona</i> sp.	1		
Order COPEPODA.			
Water fleas	2		
Order CIRRIPIEDIA (Barnacles).			
<i>Balanus amphitrite</i>		1	
<i>Chthamalus fragilis</i>		1	
Unidentified		1	
Order AMPHIPODA.			
Unidentified	18	11	
Gammaridæ (sand-fleas).			
<i>Gammarus annulatus</i>		2	
<i>Gammarus locusta</i>	1	1	
<i>Gammarus marinus</i>		3	
<i>Gammarus</i> sp.	1	1	
Podoceridæ.			
<i>Amphithœ rubricata</i>		1	
<i>Grubia compta</i>		2	
Photidæ.			
<i>Microdeutopus gryllotalpus</i>		1	
Orchestiidæ.			
<i>Hyalella azteca</i>	2		
<i>Hyalella dentata</i>		1	
<i>Hyalella knickerbockeri</i>	1		
<i>Orchestia grillus</i>		5	
<i>Talitrus megalophthalmus</i>		1	

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Crustacea (CRUSTACEANS)—Continued.			
Order ISOPODA.			
Unidentified.....	7	10	.....
Oniscidæ (sowbugs).			
<i>Oniscus asellus</i>		1	.....
Unidentified.....	2	.....	.....
Asellidæ.			
<i>Asellus</i> sp.....		2	.....
<i>Mancasellus</i> sp.....	2	.....	.....
Idotheidæ.			
<i>Edotia triloba</i>		1	.....
<i>Erichsonella attenuata</i>		2	.....
<i>Idotea balthica</i>		9	.....
<i>Idotea phosphorea</i>		3	.....
Order DECAPODA (Shrimps, Lobsters, Crabs, etc.).			
Suborder MACRURA (Shrimps, Lobsters, etc.).			
Unidentified.....	1	3	.....
Crangonidæ (sand shrimps).			
<i>Crago septemspinosus</i>		2	.....
Palæmonidæ (fresh-water shrimps).			
<i>Palæmonetes exilipes</i>	4	4	.....
<i>Palæmonetes vulgaris</i>	1	1	.....
<i>Palæmonetes</i> sp.....	1	.....	.....
Astacidæ (crawfishes).			
<i>Cambarus angustatus</i>	1	.....	.....
<i>Cambarus clarkii</i>	1	.....	.....
<i>Cambarus fallax</i>	1	.....	.....
<i>Cambarus virilis</i>	4	.....	.....
Unidentified.....	44	2	3
Suborder BRACHYURA (Crabs).			
Unidentified.....	9	16	1
Pilumnidæ (mud crabs).			
<i>Neopanope texana sayi</i>		3	.....
<i>Hexapanopeus angustifrons</i>		4	.....
Portunidæ (green crabs).			
<i>Carcinides mænas</i>		3	.....
<i>Callinectes sapidus</i> (edible crab).....		1	1
Ocypodidæ (fiddler crabs).			
<i>Uca</i> sp.....		1	.....
CLASS Myriapoda .			
Diplopoda (millipeds).....	1	.....	.....
Chilopoda (centipedes).....	7	.....	.....
CLASS Insecta (INSECTS).			
Superorder AMPHIBIOTICA (Damselflies and Dragonflies).			
Unidentified odonate nymphs and adults (few of latter).....	144	15	12
Order ZYGOPTERA (Damselflies).			
Unidentified nymphs.....	6	4	.....
Agriionidæ.....	1	.....	.....
<i>Enallagma</i> sp.....	7	.....	.....

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Insecta (INSECTS)—Continued.			
Order ANISOPTERA (Dragonflies).			
Unidentified nymphs and adults.....	21	4	
Æschnidæ.			
Gomphinae.....	2		
Æshna californica.....	1		
Æshna sp.....	1		
Anax junius.....	3	1	
Dromogomphus sp.....	1		
Libellulidæ.			
Macromia illinoensis.....	1		
Pachydiplax longipennis.....	4		
Tetragoneuria sp.....	5		
Unidentified.....	7		
Order AGNATHA (Mayflies).			
Unidentified mayflies and nymphs.....	6		
Order DERMAPTERA (Earwigs).			
Anisolabis maritima.....		1	
Order ORTHOPTERA (Grasshoppers, etc.).			
Unidentified Orthoptera and eggs.....	20	1	
Tettigidæ.			
Nomotettix sp.....	1		
Tettix ornatus.....	1		
Unidentified.....	16	1	
Acridiidæ.			
Melanoplus bivittatus.....	1		
Melanoplus sp.....	1		
Schistocerca americana.....	1		
Unidentified.....	6		
Locustidæ (green grasshoppers).....	5		
Gryllidæ (crickets).			
Nemobius sp.....	3	1	
Order PALEOPTERA (Roaches).			
Unidentified roaches and eggs.....	5		
Order MALLOPHAGA (Bird Lice).			
Unidentified.....	1		
Order HETEROPTERA (True Bugs).			
Unidentified.....	27	2	
Corixidæ (water boatmen).			
Corixa abdominalis.....	1		
Corixa harrisii.....	1		
Unidentified.....	39	11	3
Notonectidæ (back-swimmers).			
Notonecta insulata.....	1		
Notonecta sp.....		1	
Plea striola.....	3		
Nepidæ (water scorpions).			
Ranatra sp.....	7		

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Insecta (INSECTS)—Continued.			
Order HETEROPTERA (True Bugs)—Continued.			
Belostomatidæ (giant water bugs).			
<i>Zaitha</i> sp.....	69	2	5
Unidentified.....	1	2	
Naucoridæ .			
<i>Pelocoris femoratus</i>	33		10
<i>Pelocoris</i> sp.....	104	3	
Reduviidæ (assassin bugs).....	1		
Gerridæ (water striders).			
<i>Gerris marginatus</i>	1		
<i>Gerris</i> sp.....	2		
Unidentified.....	1		
Saldidæ (shore bugs).			
<i>Salda</i> sp.....	1		
Veliidæ (water walkers).			
<i>Mesovelia mulsanti</i>	1		
<i>Metrobates hesperius</i>	1		
<i>Microvelia</i> sp.....	1		
Unidentified.....	2		
Lygæidæ .			
<i>Myodocha serripes</i>	1		
Coreidæ .			
<i>Corizus sidæ</i>	2		
<i>Leptoglossus phyllopus</i>	1		
<i>Leptoglossus</i> sp.....	1		
<i>Metapodius terminalis</i>	1		
Pentatomidæ (stink bugs).			
<i>Euschistus</i> sp.....	2		
<i>Nezara</i> sp.....	1		
Unidentified.....	3		
Scutelleridæ (shield bugs).....	1		
Cydnidæ .			
<i>Geotomus robustus</i>	1		
Unidentified.....	2		
Order HOMOPTERA .			
Membracidæ (tree hoppers).			
<i>Atymna</i> sp.....	1		
<i>Ceresa</i> sp.....	1		
<i>Platycotis sagittata</i>	1		
Unidentified.....	1		
Fulgoridæ	1		
Delphacidæ	1		
Jassidæ (leafhoppers).....	2		
Aphididæ (plant-lice).....	2		
Order MEGALOPTERA (Stoneflies).			
<i>Chauliodes</i> sp. (Dobson larvæ).....	1		
<i>Corydalis</i> sp. (Dobson larvæ).....	1		
Order PHRYGANOIDEA (Caddisflies).			
<i>Molanna</i> sp.....	2	1	
Unidentified caddisflies and larvæ.....	32	13	2

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Insecta (INSECTS)—Continued.			
Order LEPIDOPTERA (Butterflies and Moths).			
Ceratocampidæ.			
<i>Anisota</i> sp. (pupæ of oak caterpillars).....	10		
Noctuidæ (cutworms).....	2	1	
Pyralidæ.....	3		
Tineidæ.....		3	
Unidentified moths.....	2		
Unidentified cocoons.....	20		
Unidentified chrysalids.....	9		
Unidentified caterpillars.....	12	3	
Order COLEOPTERA (Beetles).			
Unidentified beetles.....	135		
Cicindelidæ (tiger beetles).....	1		
Carabidæ (ground beetles).			
<i>Anomoglossus pusillus</i>	1		
<i>Bembidium nigripes</i>	1		
<i>Bembidium versicolor</i>			1
<i>Bembidium</i> sp.....	3		
<i>Clivina bipustulata</i>	1		
<i>Dyschirius</i> sp.....	1		
<i>Galerita</i> sp.....	1		
<i>Harpalus autumnalis</i>	1		
<i>Lebia analis</i>	1		
<i>Lebia ornata</i>	1		
<i>Lebia</i> sp.....	1		
<i>Loxandrus velox</i>	1		
<i>Oodes fluvialis</i>	1		
<i>Platynus striatopunctatus</i>	1		
<i>Scarites subterraneus</i>	10		1
<i>Scarites</i> sp.....	3		
Unidentified.....	18	5	
Halipidæ (crawling water beetles).			
<i>Halipus punctatus</i>	2		
<i>Halipus triopsis</i>	1	1	1
<i>Halipus</i> sp.....	3	2	
<i>Peltodytes pedunculatus</i>	4		
<i>Peltodytes</i> sp.....	4		
Unidentified.....	7		
Dytiscidæ (predacious diving beetles).			
<i>Acilius fraternus</i>	1		
<i>Agabus punctulatus</i>	1		
<i>Canthydrus bicolor</i>	17		
<i>Canthydrus puncticollis</i>	1		
<i>Canthydrus unicolor</i>	1		
<i>Canthydrus</i> sp.....	1		
<i>Celina grossula</i>	5		
<i>Celambus</i> sp.....	1		
<i>Colpius inflatus</i>	2		
<i>Colymbetes</i> sp.....	2		
<i>Copelatus glyphicus</i>	3	1	
<i>Coptotomus interrogatus</i>	3		1

TABLE II.—Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS <i>Insecta</i> (INSECTS)—Continued.			
Order COLEOPTERA (Beetles)—Continued.			
Dytiscidæ (predacious diving beetles)—Continued.			
<i>Coptotomus</i> sp.....	2		
<i>Dytiscus verticalis</i>	1		
<i>Hydrocanthus iricolor</i>	10	1	1
<i>Hydroporus modestus</i>			1
<i>Hydroporus tenebrosus</i>	1		
<i>Hydroporus</i> sp.....	1	1	
<i>Hydrovatus compressus</i>	16		
<i>Hydrovatus obesus</i>	21		
<i>Hydrovatus</i> sp.....	8		
<i>Laccophilus decipiens</i>	1		
<i>Laccophilus maculosus</i>	1		
<i>Laccophilus proximus</i>	1		
Unidentified.....	24	7	1
Gyrinidæ (whirlig beetles).			
<i>Dineutes emarginatus</i>	1		
<i>Dineutes</i> sp.....	3		
<i>Gyrinus analis</i>	1		
<i>Gyrinus elevatus</i>	1		
<i>Gyrinus</i> sp.....	2	1	
Hydrophilidæ (water scavenger beetles).			
<i>Berosus striatus</i>	1		
<i>Berosus</i> sp.....	10	4	2
<i>Cercyon</i> sp.....	3		
<i>Cymbiodyta lacustris</i> ?.....		1	
<i>Derallus altus</i>	1	1	
<i>Helopeltis larvalis</i>	1		
<i>Helophorus</i> sp.....	6		
<i>Hydrophilus triangularis</i>	2		
<i>Hydrophilus</i> sp.....	18	3	
<i>Philhydrus cinctus</i>	1		
<i>Tropisternus nimbatus</i>	2	1	4
<i>Tropisternus</i> sp.....	15		2
Unidentified.....	10	8	2
Silphidæ (carrion beetles).			
<i>Necrophorus pustulatus</i>	1		
Staphylinidæ.			
<i>Cafius bistriatus</i>		1	
<i>Lathrobium longiuscula</i>	2		
<i>Philonthus lomatus</i>	1		
Unidentified.....	5		
Scaphidiidæ (shining fungus beetles).			
<i>Scaphidium quadriguttatum</i>	1		
Erotylidæ (banded fungus beetles).			
<i>Ischyus quadripunctatus</i>	1		
<i>Megalodacne fasciata</i>		1	
Histeridæ (shining carrion beetles).			
<i>Hister dispar</i>	1		
<i>Hister vernus</i>	1		

TABLE II.—Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.

• Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS INSECTA (INSECTS)—Continued.			
Order COLEOPTERA (Beetles)—Continued.			
Parnidæ.			
<i>Elmis vittatus</i>		1	
<i>Pelonomus obscurus</i>	1		
Heteroceridæ (mud beetles) .			
<i>Heterocerus brunneus</i>	2		
<i>Heterocerus collaris</i>	1		
<i>Heterocerus tristis</i>	1		
Elatерidæ (click beetles).			
<i>Drasterius elegans</i>	1		
<i>Drasterius</i> sp.....	1		
Unidentified.....	1		
Lucanidæ (stag beetles).			
<i>Passalus cornutus</i>	1		
<i>Passalus</i> sp.....	13		
Scarabæidæ (leaf chafers).			
<i>Atænius cognatus</i>	4		
<i>Atænius strigatus</i>	6		
<i>Atænius</i> sp.....	2		
<i>Aphodius</i> sp.....	8		
<i>Canthon</i> sp.....	3		
<i>Chalepus trachypygus</i>	1		
<i>Clæotus globosus</i>	1		
<i>Onthophagus hecate</i>	1		
<i>Onthophagus pennsylvanicus</i>	1		
<i>Onthophagus</i> sp.....	2		
<i>Phanæus carnifex</i>	1		
<i>Phyllophaga</i> sp.....	1		
Unidentified.....	10		
Chrysomelidæ (leaf beetles).			
<i>Cerotoma caminea</i>	3		
<i>Donacia</i> sp.....	1	1	
<i>Halitica rufa</i>	1		
<i>Myochrous denticollis</i>	3		
<i>Ædionychis concinna</i>	1		
<i>Ædionychis scalaris</i>	1		
<i>Systema hudsonias</i>	1		
<i>Typophorus canellus</i>	1		
Unidentified.....	5		
Tenebrionidæ.			
<i>Anædus brunneus</i>	1		
<i>Blapstinus</i> sp.....	3		
<i>Opatrinus notus</i>	1		
<i>Tribolium ferrugineum</i>	1		
Unidentified.....	2		
Anthicidæ (flower beetles).			
<i>Anthicus</i> sp.....	1		
<i>Tomoderus interruptus</i>	2		

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Insecta (INSECTS)—Continued.			
Suborder RHYNCHOPHORA (Weevils).			
Unidentified.....	18	7	
Otiorhynchidæ.			
<i>Eudiagogus</i> sp.....	1		
<i>Otiorhynchus ovatus</i>		1	
Curculionidæ (snout beetles).			
Unidentified.....	1		
<i>Conotrachelus affinis</i>	1		
<i>Conotrachelus erinaceus</i>	1		
<i>Conotrachelus</i> sp.....	1		
<i>Lissorhoptrus simplex</i>	18	2	
<i>Lissorhoptrus</i> sp.....	4		
<i>Listronotus frontalis</i>	1		
<i>Pachylobius picivorus</i>	1		
<i>Sitones hispidulus</i>		1	
<i>Tylopteris pallidus</i>	2		
Calandridæ (billbugs).			
<i>Sphenophorus</i> sp.....	8	2	1
Scolytidæ (bark beetles).....	1		
Anthribidæ.			
<i>Cratoparis lunatus</i>	1		
Order DIPTERA (Flies).			
Unidentified adults.....	1	3	
Unidentified larvæ.....	14	4	
Unidentified pupæ.....	55	3	1
Tipulidæ (crane flies).			
Unidentified eggs, larvæ, pupæ, and adults.....	4	3	
Chironomidæ (midges).			
<i>Ceratopogon</i> sp.....	1		
Unidentified midges and larvæ.....	28	6	
Culicidæ (mosquitoes).			
<i>Culex restuans</i>	1		
Dixidæ.			
<i>Dixa</i> sp.....	1		
Psychodidæ (moth flies).....	1		
Cecidomyiidæ (gall midges).....	1		
Stratiomyidæ (soldier flies).			
<i>Odontomyia</i> sp.....	1		
Unidentified larvæ.....	24		1
Tabanidæ (horse flies).			
<i>Tabanus</i> sp.....	2		1
Unidentified larvæ.....	7	1	1
Dolichopodidæ.....	1	1	
Phoridæ.....	1		
Syrphidæ (flower flies).			
<i>Syrphus</i> sp.....	1		
Unidentified larvæ and pupæ.....	15	3	
Ephydridæ.			
Unidentified pupæ and adults.....	5	2	
Hippoboscidæ (bird flies).....		1	

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found*—Continued.

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Insecta (INSECTS)—Continued.			
Order HYMENOPTERA (Ants, Bees, and Wasps).			
Unidentified.....	5	3	
Apoidea (bees).....	1		
Vespoidea (wasps).....	5		
Chrysidoidea (cuckoo wasps).....	1		
Ichneumonoidea (parasitic wasps).			
<i>Hemiteles</i> sp.....	1		
<i>Phæogenes</i> sp.....	1		
Formicoidea (ants).			
Unidentified.....	33	4	
Formicidæ.			
<i>Camponotus</i> sp.....	1		
<i>Formica</i> sp.....	2		
<i>Pheidole dentata</i>	1		
<i>Ponera opaciceps</i>	1		
Unidentified.....	2		
Tenthredinoidea (sawflies).....	3		
CLASS Arachnida .			
Order ARANEIDA (Spiders).			
Unidentified spiders and cocoons.....	27	2	
<i>Schizogyna</i> sp.....		1	
Order ACARIDA (Mites).			
Hydrachnidæ (water mites).....	14	1	
Oribatidæ.....	1		
SUBKINGDOM Mollusca ¹ (MOLLUSKS).			
Unidentified.....	20	31	
CLASS Gastropoda (UNIVALVES).			
Unidentified.....	561	71	13
Muricidæ.			
<i>Nucella lapillus</i>		1	
<i>Urosalpinx cinereus</i>		1	
Nassidæ.			
<i>Ilyanassa obsoleta</i>		8	1
<i>Nassa acuta</i>	1		
<i>Nassa ambigua</i>	1		
<i>Nassa</i> sp.....		6	
Columbellidæ.			
<i>Anachis avara</i>		4	
<i>Anachis obesa</i>	4	4	
<i>Astyris lunata</i>	3	7	
Pleurotomidæ.			
<i>Clathurella jewetti</i>		1	
<i>Mangilia stellata</i>		1	
<i>Mangilia</i> sp.....	1		

¹ Besides the species here listed for the southern black duck, Mr. F. C. Baker (O. & O. 14, p. 139, and Proc. Acad. Nat. Sci. Philadelphia, 1889, p. 267) adds the following: *Cylichna oriza*, *Utricularia canaliculatus*, *Truncatella subcylindrica*, and *Odostomia impressa*.

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Gastropoda (UNIVALVES)—Continued.			
Calyptræidæ.			
<i>Crepidula convexa</i>		1	
<i>Crepidula fornicata</i>		1	
Pyramidellidæ.			
<i>Odostomia impressa</i>		1	
<i>Odostomia menestho trifida</i>		1	
<i>Odostomia</i> sp.....		1	
<i>Turbonilla</i> sp.....		1	
Litorinidæ.			
<i>Lacuna vineta</i>		2	
<i>Lacuna</i> sp.....		6	
<i>Litorina grönlandica</i>		1	
<i>Litorina irrorata</i>		2	
<i>Litorina litorea</i>	1	22	
<i>Litorina palliata</i>		16	
<i>Litorina rudis</i>		38	
<i>Litorina</i> sp.....	1	5	
Modiolidæ.			
<i>Modulus modulus</i>	1		
Cerithiidæ.			
<i>Bittium nigrum</i>		3	
<i>Bittium</i> sp.....		1	
Rissoidæ.			
<i>Paludinella salsa</i>		1	
Amnicolidæ.			
<i>Amnicola limosa</i>			1
<i>Amnicola olivacea</i>	1		
<i>Amnicola parva</i>	1		
<i>Amnicola peracuta</i>	8		
<i>Amnicola porata</i>	1		
<i>Amnicola</i> sp.....	6	3	3
<i>Paludetrina</i> sp.....	3		
Valvatidæ.			
<i>Valvata sincera</i>	4		
<i>Valvata tricarinata</i>	2		
<i>Valvata virens</i>	5		
<i>Valvata</i> sp.....	1		
Viviparidæ.			
<i>Vivipara intertexta</i>	5		
<i>Campeloma indecisa</i>	1		
<i>Campeloma</i> sp.....		1	
Ampullariidæ.			
<i>Ampullaria</i> sp.....	3		
Neritidæ.			
<i>Neritina reclinata</i>	35		
<i>Neritina virginica</i>	3	2	
Trochidæ.			
<i>Margarites helicinus</i>		1	

TABLE II.—Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined.....	1,725	622	51
CLASS Gastropoda (UNIVALVES)—Continued.			
Triforidæ.			
<i>Triforis</i> sp.....		1	
Cylichnidæ.			
<i>Cylichna canaliculata</i>		1	
Zonitidæ.			
<i>Vitrea</i> sp.....	1		
Helicidæ.			
<i>Polygyra espiloca</i>	1		
<i>Polygyra</i> sp.....	3		
Pupidæ.			
<i>Vertigo</i> sp.....	1		
Succineidæ.			
<i>Succinea avara</i>		1	
Auriculidæ.			
<i>Melampus bidentatus</i>		2	
Lymnæidæ.			
<i>Lymnæa columella</i>	1		
<i>Lymnæa palustris</i>	3		
<i>Lymnæa techella</i>		1	
<i>Lymnæa truncatua</i>	1		
<i>Lymnæa</i> sp.....	6	1	
<i>Planorbis alabamensis</i>	1		
<i>Planorbis campanulatus</i>	1	1	
<i>Planorbis dilatatus</i>	1		
<i>Planorbis duryi</i>			4
<i>Planorbis exacuus</i>	1		
<i>Planorbis hirsutus</i>	1		
<i>Planorbis opercularis</i>	2		
<i>Planorbis parvus</i>	8		
<i>Planorbis trivolvus</i>	13		7
<i>Planorbis vermicularis</i>	1		
<i>Planorbis wheatleyi</i>	1		
<i>Planorbis</i> sp.....	15	1	
<i>Pompholyx costata</i>	1		
<i>Segmentina armigera</i>	4		
<i>Segmentina obstricta</i>	1		
Physidæ.			
<i>Physa ancillaria</i>	1		
<i>Physa heterostrophæ</i>	15	1	
<i>Physa</i> sp.....	24	2	2
CLASS Pelecypoda (BIVALVES).			
Unidentified.....	16	9	1
Myidæ.			
<i>Mya arenaria</i> (soft-shell clam).....		1	
Mactridæ.			
<i>Mulinia lateralis</i>			1
<i>Rangia cuneata</i>	1		
Tellinidæ.			
<i>Macomia fusca</i>		1	

TABLE II.—*Items of animal food identified in stomachs of mallard ducks and the number in which found—Continued.*

Kind of food.	Common mallard.	Black duck.	Southern black duck.
Total number of stomachs examined	1,725	622	51
CLASS Pelecypoda (BIVALVES)—Continued.			
Veneridæ.			
<i>Gemma gemma</i>	1	2	
<i>Gemma purpurea</i>		1	
<i>Paphia staminea</i>	1		
Sphæriidæ.			
<i>Corneocyclas abdita</i>	3	2	
<i>Corneocyclas milium</i>	1		
<i>Corneocyclas splendida</i>	1		
<i>Corneocyclas variabile</i>	1		
<i>Corneocyclas vesiculare</i>	1		
<i>Corneocyclas virginicum</i> ?		2	
<i>Corneocyclas</i> sp.	6		
<i>Sphærium partumeium</i>	2		
<i>Sphærium</i> sp.	4		
Cardiidæ.			
<i>Cardium grönlandicum</i>		1	
Unionidæ.			
<i>Unio</i> sp.	1		
Nuculidæ.			
<i>Nucula delphinodonta</i>		1	
<i>Nucula proxima</i>		1	
Mytilidæ.			
<i>Mytilus edulis</i> (common mussel)	1	35	
<i>Modiola plicatula</i>		3	
SUBKINGDOM CHORDATA (VERTEBRATES).			
CLASS Pisces (FISHES).			
Unidentified	36	18	3
Anguillidæ (eels).			
<i>Anguilla chrysypa</i>		1	
Pœciliidæ (killfishes).			
<i>Fundulus</i> sp.		2	
Cyprinodontidæ (top minnows).			
<i>Cyprinodon variegatus</i>	3		
CLASS Amphibia (FROGS, TOADS, AND SALAMANDERS).			
Ranidæ (frogs)	19	1	
CLASS Mammalia (MAMMALS).			
Bit of mammal bone		1	

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UNITED STATES DEPARTMENT OF AGRICULTURE



BULLETIN No. 721



Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

November 22, 1918

THE BEET-SUGAR INDUSTRY IN THE UNITED STATES.

By C. O. TOWNSEND,

Pathologist in Charge, Office of Sugar-Plant Investigations.

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BEET-SUGAR MILLS IN THE UNITED STATES.

In the United States in 1916, 84 beet-sugar mills were standing and equipped for extracting and refining sugar from beet roots. The first of these had been built in 1870 at Alvarado, Cal. During the summer of 1916, 7 of the 84 mills had been erected and equipped for the campaign of 1916-17, and 15 additional were built and equipped for the handling of the 1917-18 crop, making a total of 99 beet-sugar mills now standing. (Table I.)

During this period of 47 years, 5 other mills were built, 3 of which have burned, 1 has been dismantled, and 1 has been utilized for some purpose other than that of making beet sugar. Of the 99 beet-sugar mills now standing (fig. 1), 19 were first erected at some point other than the place where they are now located; but owing to certain limit-

ing factors in beet-sugar production these 19 mills have been removed to other locations (fig. 2¹ and Table II); 2 of these were built in



FIG. 1.—Outline map of the United States, showing beet-sugar mills in operation (o) and those standing idle (x) in 1917.

Canada and removed to the United States, and 1 was built in this country and removed to Canada.

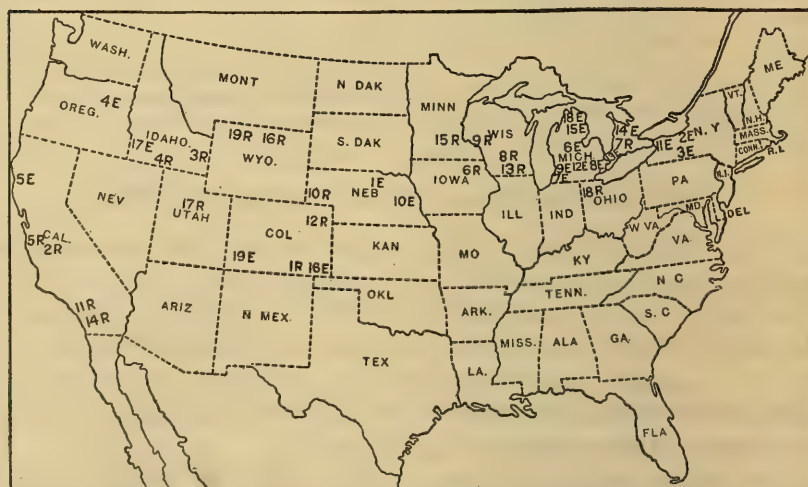


FIG. 2.—Outline map of the United States, showing the original location of 19 beet-sugar mills (E) and the points to which they were removed (R).

¹ In this figure 1E shows the original location of mill No. 1 and 1R the point to which that mill was removed; 2E the original location of mill No. 2 and 2R the point to which it was removed; and so on for each mill listed in Table II.

TABLE I.—*American beet-sugar mills in 1917.*

No.	Location.		Date of erection.	Name of company.	Capacity. ¹		Date enlarged.
	State.	Town.			Original.	Present.	
1	California	Alvarado	1870	Alameda Sugar Co.	50	800	1894 ²
2	Nebraska	Grand Island	1890	American Beet Sugar Co.	350	500	1916
3	Utah	Lehi	1891	Utah-Idaho Sugar Co.	300	1,250	1900
4	California	Chino	1891	American Beet Sugar Co.	400	1,100	1895
5	do.	Los Alamitos	1897	Los Alamitos Sugar Co.	350	800	1898
6	Wisconsin	Menomonee Falls	1897	Wisconsin Sugar Co.	500	690	1901
7	Utah	Ogden	1898	Amalgamated Sugar Co.	350	500	1912
8	California	Oxnard	1898	American Beet Sugar Co.	2,000	3,000	.....
9	do.	Betteravia	1899	Union Sugar Co.	500	1,000	1908
10	do.	Spreckels	1899	Spreckels Sugar Co.	3,000	4,500	.....
11	Washington	Waverly	1899	Washington State Sugar Co.	350	500	1906
12	Colorado	Grand Junction	1899	Western Sugar & Land Co.	350	700	1906
13	Michigan	Holland	1899	Holland-St. Louis Sugar Co.	350	500	.....
14	do.	Bay City	1899	Michigan Sugar Co.	600	1,400	1912
15	do.	Alma	1899	do.	600	1,400	1912
16	do.	West Bay City	1899	West Bay City Sugar Co.	500	900	.....
17	do.	Caro	1899	Michigan Sugar Co.	600	1,200	1902
18	Colorado	Rocky Ford	1900	American Beet Sugar Co.	1,000	1,800	1912
19	do.	Sugar City	1900	National Sugar Manufacturing Co.	500	500	1916
20	Ohio	Fremont	1900	Continental Sugar Co.	350	468	.....
21	Michigan	Marine City	1900	Western Sugar Refining Co.	350	600	.....
22	do.	Salzburg (West Bay City)	1901	Columbia Sugar Co.	400	1,500	1907
23	do.	Lansing	1901	Owosso Sugar Co.	600	600	.....
24	Colorado	Loveland	1901	Great Western Sugar Co.	1,000	2,000	1912
25	Utah	Logan	1901	Amalgamated Sugar Co.	400	600	1912
26	Colorado	Greeley	1902	Great Western Sugar Co.	700	1,000	1911
27	do.	Eaton	1902	do.	600	1,100	1911
28	Michigan	Carrollton	1902	Michigan Sugar Co.	800	900	.....
29	do.	Mount Clemens	1902	Mount Clemens Sugar Co.	600	600	.....
30	do.	Croswell	1902	Michigan Sugar Co.	600	750	.....
31	do.	Sebewaing	1902	do.	600	850	.....
32	Utah	Garland	1903	Utah-Idaho Sugar Co.	700	750	.....
33	Idaho	Idaho Falls	1903	do.	600	750	1995
34	Michigan	St. Louis	1903	Holland-St. Louis Sugar Co.	500	600	.....
35	do.	Menominee	1903	Menominee River Sugar Co.	1,000	1,200	1907
36	do.	Owosso	1903	Owosso Sugar Co.	1,000	1,200	1907
37	Colorado	Fort Collins	1903	Great Western Sugar Co.	1,200	2,150	1911
38	do.	Windsor	1903	do.	600	1,100	1911
39	do.	Longmont	1903	do.	600	2,100	1911
40	Wisconsin	Chippewa Falls	1904	Chippewa Sugar Refining Co.	600	600	.....
41	do.	Janesville	1904	Rock County Sugar Co.	600	700	.....
42	Idaho	Blackfoot	1904	Utah-Idaho Sugar Co.	600	700	1911
43	do.	Sugar	1904	do.	700	900	.....
44	Utah	Lewiston	1905	Amalgamated Sugar Co.	600	800	1911
45	Michigan	Blissfield	1905	Continental Sugar Co.	600	868	.....
46	Illinois	Riverdale	1905	Charles Pope, Chicago	350	500	.....
47	Colorado	Lamar	1905	American Beet Sugar Co.	400	500	1907
48	do.	Sterling	1905	Great Western Sugar Co.	600	1,100	1912
49	Wisconsin	Madison	1905	United States Sugar Co.	600	600	.....
50	Arizona	Glendale	1905	Southwestern Sugar & Land Co.	800	800	(²)
51	Colorado	Brush	1906	Great Western Sugar Co.	750	1,100	1912
52	do.	Fort Morgan	1906	do.	600	1,150	1912
53	do.	Swink	1906	Holly Sugar Corporation	1,200	1,200	.....
54	Montana	Billings	1906	Great Western Sugar Co.	1,200	2,050	1912
55	Kansas	Garden City	1906	Garden City Sugar & Land Co.	1,000	1,000	.....
56	California	Visalia	1906	San Joaquin Valley Sugar Co.	350	400	.....
57	do.	Hamilton City	1906	Sacramento Valley Sugar Co.	600	700	.....
58	Minnesota	Chaska	1906	Minnesota Sugar Co.	600	800	.....
59	Colorado	Las Animas	1907	American Beet Sugar Co.	700	1,000	.....
60	Iowa	Waverly	1907	Iowa Sugar Co.	400	500	.....
61	California	Corcoran	1908	Pacific Sugar Corporation	600	600	.....
62	do.	Santa Ana	1908	Southern California Sugar Co.	600	600	(³)

¹ Number of tons of beets that may be sliced each 24 hours.² Rebuilt in 1879, 1887, and 1889.³ Acquired by the Holly Sugar Corporation.

TABLE I.—*American beet-sugar mills in 1917*—Continued.

No.	Location.		Date of erection.	Name of company.	Capacity.		Date enlarged.
	State.	Town.			Original.	Present.	
63	Nebraska.....	Scottsbluff.....	1910	Great Western Sugar Co....	1,200	1,850	1912
64	Ohio.....	Paulding.....	1910	Columbia Sugar Co.....	700	800	
65	do.....	Findlay.....	1911	Continental Sugar Co.....	600	871	
66	Utah.....	Elsinore.....	1911	Utah-Idaho Sugar Co.....	500	500	
67	Nevada.....	Fallon.....	1911	Nevada-Utah Sugar Co.....	500	500	
68	California.....	Anaheim.....	1911	Anaheim Sugar Co.....	500	850	1911
69	do.....	Huntington Beach.....	1911	Holly Sugar Corporation.....	750	1,200	1912
70	do.....	Santa Ana (Dyer).....	1912	Santa Ana Sugar Co.....	600	1,200	1914
71	Idaho.....	Burley.....	1912	Amalgamated Sugar Co.....	400	600	1912
72	Ohio.....	Toledo.....	1912	Toledo Sugar Co.....	1,000	1,100	
73	do.....	Ottawa.....	1912	Ottawa Sugar Co.....	600	600	
74	Indiana.....	Decatur.....	1912	Holland-St. Louis Sugar Co.....	700	800	
75	Utah.....	Payson.....	1913	Utah-Idaho Sugar Co.....	500	700	
76	do.....	Layton.....	1915	Layton Sugar Co.....	500	700	
77	Wyoming.....	Sheridan.....	1915	Holly Sugar Corporation.....	600	900	
78	do.....	Lovell.....	1916	(Big Horn Basin Sugar Co. } Great Western Sugar Co. }	600	750	1916
79	Idaho.....	Twin Falls.....	1916	Amalgamated Sugar Co.....	600	600	
80	Nebraska.....	Gering.....	1916	Great Western Sugar Co.....	1,000	1,000	
81	Utah.....	Spanish Fork.....	1916	Utah-Idaho Sugar Co.....	750	1,000	1916
82	do.....	West Jordan.....	1916	do.....	500	500	
83	do.....	Brigham.....	1916	do.....	500	500	
84	Oregon.....	Grants Pass.....	1916	do.....	500	500	
85	Idaho.....	Paul.....	1917	Amalgamated Sugar Co.....	500	500	
86	Utah.....	Smithfield.....	1917	do.....	600	600	
87	do.....	Delta.....	1917	Delta Beet Sugar Co.....	1,000	1,000	
88	Colorado.....	Brighton.....	1917	Great Western Sugar Co.....	1,000	1,000	
89	Nebraska.....	Bayard.....	1917	do.....	800	800	
90	Montana.....	Missoula.....	1917	do.....	1,000	1,000	
91	do.....	Hamilton.....	1917	Montana-Utah Sugar Co.....	500	500	
92	Iowa.....	Mason City.....	1917	Northern Sugar Corporation.....	1,200	1,200	
93	California.....	Tracy.....	1917	Pacific Sugar Corporation.....	600	600	
94	do.....	Manteca.....	1917	Spreeckels Sugar Co.....	1,000	1,000	
95	Utah.....	Moroni.....	1917	People's Sugar Corporation.....	400	400	
96	do.....	Cornish.....	1917	West Cache Sugar Co.....	500	500	
97	Idaho.....	Shelley.....	1917	Utah-Idaho Sugar Co.....	600	600	
98	Wyoming.....	Worland.....	1917	Wyoming Sugar Co.....	600	600	
99	Washington.....	North Yakima.....	1917	Utah-Idaho Sugar Co.....	600	600	

Of the three mills that were burned, little is known about the actual working of the one at Staunton, Va., or the one at Eddy, N. Mex. The former operated for two years and the latter for three years, but evidently they were not sufficiently successful to warrant rebuilding them. They were of small capacity and constructed from second-hand material. The mill formerly at St. Louis Park, Minn., which was burned in 1906, operated with fair success during each of the seven years of its existence. The mill at Watsonville, Cal., which was erected in 1888, was closed in 1899 and has since been dismantled. The mill at Pekin, Ill., erected in 1899, was closed in 1890 and has since been transformed into a glucose plant. Further data regarding these five mills are given in Table III.

TABLE II.—Original and present locations of the removed beet-sugar mills.

No.	Date of erection.	Where built.		Date removed.	Present location.		Capacity (tons).	Original owners.
		State.	Town.		State.	Town.		
1...	1891	Nebraska...	Norfolk.....	1905	Colorado....	Lamar.....	350	Norfolk Beet Sugar Co.
2...	1897	New York...	Rome.....	1905	California...	Visalia.....	200	First New York Beet Sugar Co.
3...	1898	do.....	Binghamton	1904	Idaho.....	Blackfoot...	350	Binghamton Beet Sugar Co.
4...	1898	Oregon.....	La Grande...	1912	do.....	Burley.....	350	Oregon Sugar Co.
5...	1898	California...	Crockett.....	1908 ¹	California...	Corcoran...	500-1,000	California Beet Sugar Refining Co.
6...	1898	Michigan...	Bay City....	1907	Iowa.....	Waverly....	350-500	Michigan Sugar Co.
7...	1899	do.....	Benton Harbor.	1902	Ontario.....	Berlin.....	350	Wolverine Sugar Co.
8...	1899	do.....	Rochester...	1905	Wisconsin...	Madison....	500	Detroit Sugar Co.
9...	1899	do.....	Kalamazoo...	1904	do.....	Chippewa Falls.	500	Kalamazoo Sugar Co.
10...	1899	Nebraska...	Leavitt.....	1910	Nebraska...	Scottsbluff	500-1,100	Standard Beet Sugar Co.
11...	1900	New York...	Lyons.....	1911	California...	Anaheim....	600	Empire State Sugar Co.
12...	1901	Michigan...	Saginaw.....	1905	Colorado....	Sterling....	600	Saginaw Sugar Co.
13...	1902	Ontario.....	Dresden.....	1904	Wisconsin...	Janesville...	600	Dresden Sugar Co.
14...	1902	do.....	Warton.....	1908	California...	Santa Ana...	350	Colonial Sugar Co.
15...	1903	Michigan...	East Tawas...	1906	Minnesota...	Chaska.....	600	Tawas Sugar Co.
16...	1905	Colorado....	Holly.....	1915	Wyoming...	Sheridan....	600	Holly Sugar Co.
17...	1906	Idaho.....	Nampa.....	1916	Utah.....	Spanish Fork	750	West Idaho Sugar Co.
18...	1906	Michigan...	Charlevoix...	1912	Ohio.....	Ottawa.....	600	West Michigan Sugar Co.
19...	1911	Colorado....	Monte Vista.	1916	Wyoming...	Lovell.....	600	San Luis Valley Sugar Co.

The 99 mills now standing are for the most part favorably situated for extracting and refining beet sugar under present conditions. In many instances certain limiting factors will need careful consideration and readjustment before a sufficient quantity of raw material can be assured annually to make all of them permanently successful under normal conditions as beet-sugar centers. In many areas beet-sugar mills have been crowded in too rapidly, so that it has not been possible to readjust the farming operations and install the required drainage, irrigation, etc., with sufficient rapidity to provide the necessary well-prepared acreage of sugar beets to insure a normal mill run. Consequently neither the mill owners nor the growers have received under these conditions a maximum return for the money and labor invested.

TABLE III.—Beet-sugar mills destroyed or used for other purposes than making sugar.

No.	Location.		Date erected.	Name of company.	Capacity.	Present status.
	State.	Town.				
1...	California....	Watsonville...	1888	Western Beet Sugar Co.....	1,000	Closed, ¹ 1899.
2...	Virginia.....	Staunton.....	1892	O. K. Lapham.....	(²)	Burned, 1894.
3...	New Mexico...	Eddy.....	1896	Pecos Valley Beet Sugar Co.....	200	Burned, 1903.
4...	Minnesota...	St. Louis Park	1898	Minnesota Sugar Co.....	350	Burned, 1905.
5...	Illinois.....	Pekin.....	1899	Illinois Sugar Refining Co.....	700	Closed, ³ 1890.

¹ Dismantled.² Not known.³ Glucose plant, 1902.

For several years the Office of Sugar-Plant Investigations, jointly with the Office of Farm Management and independently, has been studying the agronomic conditions found in each of the existing and in some of the prospective sugar-beet centers. It is the purpose of this paper to discuss the conditions which have been brought out in these studies and to point out in a general way the factors that are favorable and those that are unfavorable for the production of sugar beets. The primary object of this paper, therefore, is to give a general survey of the beet-sugar industry and to encourage the more general application of those principles and practices which make for better returns to the grower and to discourage those practices which tend to reduce the yields and quality of sugar beets and of other crops and to unbalance the relation between crop production and the kind, number, and quality of the live stock on the beet farms, the ultimate object being an increased production of sugar and a stabilization of the beet-sugar industry.

SOIL.

Almost any fertile soil capable of producing good crops of other kinds will, if properly handled, produce good sugar beets. More depends upon the physical condition of the soil and the way in which it is handled than upon the so-called kind or type of soil. Extremely sandy soil or soil of a decidedly gravelly type is not usually satisfactory for sugar-beet growing.

Raw soil.—Generally speaking, raw soil or new soil does not produce as large yields of sugar beets as may be obtained from soil that has been under cultivation for some time. In recent years much new soil has been brought under cultivation through the use of the sugar beets; this in a measure has had a tendency to reduce the average yield of sugar beets in this country. The argument in favor of growing sugar beets on new soil is that this crop will bring the raw soil under control and place it in good tilth for other crops more quickly than almost any other crop now produced on a large scale on American farms. It must be expected, therefore, that so long as new sugar-beet territories are being opened in the partially developed sections of the United States this factor, tending to keep down the average yield of beet roots, will be effective. Also in many of the older sugar-beet sections in which the growing of sugar beets is being extended from year to year, whereby new lands are being brought under cultivation, this factor will be more or less effective in holding down the average yield. In those sections where sugar beets have been grown for many years, as, for example, in Utah, and in which a minimum acreage of new soil is being brought in from year to year, the average yield of beets per acre is strikingly above the average for the entire

country. Usually the grower who utilizes new soil for sugar-beet production expects a comparatively low yield and is generally satisfied, for the reason stated above, if the crop pays the cost of production. While this is one of the causes of the low-average yield of beets per acre in this country, it is by no means the only one.

Worn soil.—In those sugar-beet sections where this crop has been grown for a number of years without proper attention to the maintenance of soil fertility and an adequate supply of humus, the yield of sugar beets has been reduced. There are few sugar-beet areas in which the soil fertility has been maintained or improved to the limit of possibilities. It is apparent, therefore, that by proper attention to soil conditions from the standpoint of fertility the average yield of beets per acre may be greatly increased. The worn condition of the soil is not due alone to the growing of sugar beets. All other farm crops when grown without reference to increasing the supply of available plant food in the soil and without proper attention to the humus in the soil tend to reduce the yielding value of the soil.

Sugar beets are no harder upon the soil than are the other crops generally grown; all require the same plant foods in slightly different proportions. If not supplied with the material removed by the various crops or if the plant foods in the soil are not made available by the application of humus and by proper cultivation, the soil becomes worn and infertile, and the yields of all crops, including sugar beets, are greatly reduced.

Quality of the soil.—Soils vary widely in their original qualities, both physical and chemical. All agricultural soils are supplied in varying proportions with the necessary plant foods for crop production. Soils that have plant food present in great abundance may be said to be rich. They are not fertile, however, unless these plant foods are in soluble form or unless they are rendered soluble as rapidly as the various materials are required by the plant in the process of growth. The quality of the soil from the standpoint of fertility may be greatly improved by proper cultivation, crop rotation, and the addition of humus, as well as by the application of lime or other material that will improve its physical condition. In special cases special treatments, such as subsoiling and drainage, are needed to make the soil highly productive.

SUBSOIL.

In the growing of sugar beets the subsoil is often of equal importance with the surface soil.

Hardpan.—Frequently the surface soil is underlain by a hardpan which it is impossible for the beet roots to penetrate. The hardpan may be of natural formation or it may be induced by improper

tillage. If it is close to the surface and of such material that it can not be broken up successfully, the growing of sugar beets suitable for sugar making is impossible. Beets produced under such conditions will be short, with a resulting low tonnage, or they will be pushed out of the ground and consequently will be low in sugar and purity. The nature of the hardpan is of considerable importance in this connection. If it is of rock and near the surface little can be done to improve its condition for sugar-beet culture, but if it is simply a close and compact form of soil it may be broken up with a subsoil plow. An extremely hard subsoil is sometimes found in the sugar-beet sections, especially in local areas, and this condition sometimes constitutes a limiting factor in the production of this crop in those areas as a whole or on certain farms or fields, depending upon the location and distribution of the hardpan. If the hardpan is present at a great depth it may result in holding too much moisture in the surface soil, thereby rendering the conditions unfavorable for sugar-beet production; if the hardpan in this case has sufficient slope to carry the water off, the unfavorable condition may be relieved by proper drainage.

Porous soil.—The reverse of the preceding condition is sometimes found in sugar-beet sections in which the porous subsoil is of such a nature and of such a depth that great difficulty is experienced in keeping the soil supplied with moisture during the growing season. Rain or irrigation water passes rapidly through the subsoil and is soon out of reach of the growing plant. If the porous subsoil is very deep and extremely porous the ground is unsuited for sugar-beet culture. Frequently something can be done to relieve this condition to a limited extent by proper cultivation and by supplying the surface soil with sufficient humus to enable it to retain enough moisture to produce a fair crop. A heavy crop of beets can not be expected on a thin surface soil underlain with an extremely porous subsoil.

TOPOGRAPHY.

The unfavorable topography of an area is frequently the limiting factor in the production of sugar beets. Mountainous areas can not be utilized for the development of the beet-sugar industry unless the valleys are sufficiently large to support a mill or are favorably located with reference to an existing mill and composed of sufficient fertile, tillable soil so that beets of proper quality and in sufficient quantity can be produced at a reasonable cost. Many small valleys, especially in the western United States, might be utilized in the growing of sugar beets were it not for the fact that they are too small to support a sugar mill and too far from existing mills to permit the beet roots to be transported at a sufficiently low cost.

This problem may be solved by utilizing some practical means of drying the beet roots. It is possible to reduce the weight of the root by about 75 per cent without changing the quality or lessening the quantity of sugar present. If this can be done with sufficient rapidity and at a sufficiently low cost it will be possible to handle to advantage the product of many small valleys and other limited areas. A sugar mill can not be financially successful under normal conditions unless it is supplied with a sufficient quantity of raw material to produce a run of approximately 100 days each year, and it is desirable that a considerable part of the supply be within wagon haul of the mill. Any factor which reduces the working capacity or the operating time of a sugar mill increases the cost of production of the sugar. The small valleys mentioned above are sometimes used to supplement the beet crop produced in other sections provided the hauling distance by wagon or rail is not too great.

Hills.—Generally a hilly country is not satisfactory for sugar-beet culture, especially if the hills are inclined to wash. The nature of the soil of the hills is an important factor in determining whether sugar beets can be grown. Hauling heavy loads in a hilly country is also a matter of serious consideration. Usually from 3 to 5 tons of beets are hauled at each load, and if hills must be climbed the loads must necessarily be reduced and the cost of hauling consequently increased. This in itself may be a limiting factor in the production of sugar beets in some otherwise favorable sugar-beet areas.

Level land.—In irrigated countries it is desirable that the surface of the soil be sufficiently level to permit uniform irrigation. An extremely level area, however, is objectionable because of the difficulty in spreading the water over the entire field with sufficient rapidity. This is especially objectionable in the case of sugar beets, which should be watered between the rows only, as shown in Plate I, figure 2. Again when the land, especially in irrigated sections, is very level alkali frequently appears on the surface after repeated irrigations. Sugar beets will tolerate a small amount of alkali, but all crops are injured by excessive quantities of alkali in the soil, especially when the plants are young and tender.

Rolling.—Other things being equal moderately rolling land is more desirable for sugar-beet culture than either extremely hilly or very level areas. This is especially true in those sections where sugar beets are produced under rainfall conditions. In irrigated sections rolling land is not as desirable unless the topography of the country is such that the area under cultivation can be irrigated readily. Under irrigation conditions it is desirable that the land have an even surface with a gentle slope of at least 7 feet to the mile. If the slope is too marked the irrigation water passes over it too rapidly unless special care is taken in applying the water.

CLIMATE.

One of the most important factors in determining the suitability of a given area for sugar-beet culture is the climate. Frequently all other conditions are favorable, while some climatic factor renders sugar-beet growing unprofitable.

Temperature.—Successful sugar-beet growing has been confined to the temperate region in practically all beet-sugar producing countries. Frequently sugar beets will produce a satisfactory tonnage of roots in warmer areas, but for some reason they generally are not sufficiently rich in sugar to make them profitable in sugar making. This is notably the case in nearly all parts of the southern United States. Occasionally areas are found in these warmer zones where sugar beets may be grown successfully. This is true in southern California and in some parts of Arizona and New Mexico, where the adverse condition of temperature is overcome by growing the beets during the so-called winter months or at least by getting the plants started in the winter or early spring. In some sections the elevation and the temperature of the prevailing wind are sufficient to modify the climate so that sugar beets may be produced with profit. If the winter months are too cold for the production of beets and the summers too warm for the proper storage of sugar in the roots, the limiting factor is established which renders profitable sugar-beet growing impossible with any of our known varieties. Should it become desirable to extend the culture of sugar beets into the warmer sections of the country, it is possible that suitable varieties could be developed that would be profitable from the standpoint of both tonnage and quality.

Another important consideration is the fact that high temperatures tend to encourage spoilage. This may be overcome by passing the beets through the mill as rapidly as they are harvested and by harvesting the roots as soon as they are matured. Regarding the lower temperatures, sugar beets have been successfully grown in practically all of our Northern States, and several beet-sugar mills are operated successfully in Canada. It is apparent, therefore, that the lower temperatures do not constitute a limiting factor in sugar-beet growing in any of our agricultural sections. It would seem that a short growing season would render sugar-beet production unprofitable in many northern areas, but the sugar beet is readily adaptable to many adverse factors, and usually in those sections where the growing season is short the sugar beet grows rapidly and stores sugar in great abundance. Some of our most satisfactory sugar-beet sections, therefore, are to be found in our more northern States.

During the period just preceding the beet harvest the difference in temperature between day and night is an important condition in

the development and storage of sugar. The young beet plant very early in its life begins to store sugar, but its maximum activity along this line is reached in the fall, when the difference in temperature between night and day is most apparent. This difference seems to be necessary for the proper elaboration and storage of sugar and is apparently a limiting factor in the production of sugar-beet roots sufficiently rich in sugar to make them profitable for sugar-making purposes. It is probable that the absence of cool nights at the end of the growing season permits the continued growth and development of the beets, thereby using up the sugar in plant growth instead of storing it.

Moisture.—Moisture is necessary for the production of profitable crops of sugar beets. This reaches the soil in the form of rain or snow, or it may be applied artificially. Our present sugar-beet area extends over a portion of the humid and the irrigated sections of the country, as shown in figure 1.

In the humid sections the moisture falls largely during the winter months, although there are usually frequent rains during the spring and summer. Occasionally some parts of the humid portion of our sugar-beet area are visited by heavy rains in the early spring, which greatly delay the planting of the beets as well as of other crops. This is sometimes followed about midsummer by a severe drought which greatly retards crop growth. If these conditions were of frequent occurrence over wide areas they would constitute a limiting factor in sugar-beet growing in the humid sections; but they have occurred in this country only in limited areas and at long intervals. Occasionally rainfall is abundant at harvesting time, sometimes injuring the sugar-beet crop by producing a second growth of the plants, which greatly reduces the sugar content. The extent of this injury depends upon the condition of the beets and the duration of the rainy period. If this is followed by a period of favorable weather the sugar content will be restored wholly or in part, depending upon the duration and nature of the weather. It sometimes happens that the beets must be harvested before the lost sugar is fully restored, either to prevent the roots from freezing in the ground or to avoid a temporary shutdown of the mill. Consequently, a second growth due to late rains may cause serious losses to the grower and to the sugar company. A season in the humid region in which the rainfall is just sufficient to maintain a steady growth until near harvesting time, followed by continuous fair weather accompanied by cool nights and warm days, makes conditions most favorable for the production of sugar beets so far as the humid area is concerned. These conditions prevail generally in the humid sections where sugar beets are grown.

In the irrigated sugar-beet areas usually less than 20 inches of moisture falls during the entire year, and frequently many of the showers are so light that they are of no practical benefit in crop production. Sugar-beet growers in those sections depend largely upon irrigation. Frequently the showers that fall in irrigated areas are detrimental rather than helpful in the production of sugar beets, since they frequently cause the soil to crust. If this crusting occurs shortly after the seed is sown the young plants have great difficulty in breaking through to the light, with the result that the stands are very seriously injured and replantings are necessary. If the showers occur soon after the beets are up and the ground crusts around the young plants, the air is cut off from the roots and growth is interfered with. This may sometimes be remedied by prompt cultivation, although the plants are often so firmly embedded in the crust that cultivation is difficult without serious injury to the plants. Sometimes a moderately heavy roller of one of the types shown in Plate II will produce the desired result in breaking the crust. In irrigated sections every effort should be made to retain the fall or winter moisture in the soil, and if the ground is dry in the fall, irrigation is generally desirable. The soil should be sufficiently moist when the seed is planted to produce prompt and complete germination, and there should be sufficient moisture in the soil to maintain a steady growth for several weeks. As soon as the plants indicate that they are suffering from lack of moisture they should be irrigated. When beets wilt during the day and fail to revive at night they should be watered without delay. Usually from one to three irrigations during the growing season are sufficient to produce a crop in most of the irrigated sections where sugar beets are grown. When beets are irrigated the soil should be thoroughly wet, and every effort should then be made to retain the moisture as long as possible by frequent cultivation.

Sunshine.—The third element of climate which has a marked effect on the quality of sugar beets is light, over which man has little control except in the selection of locality. It is generally believed that direct sunshine is an important factor in the production and storage of sugar in the beet. Observation indicates, however, that diffused light is almost, if not quite, as effective in producing and storing sugar as direct sunlight. The importance of light should not be overlooked, however, since without it the leaves could not manufacture sugar. Beet sugar is all made in the beet leaves by the action of light upon the leaf green when moisture and carbonic-acid gas are present. Without light this action in the leaf can not take place, no matter how favorable may be all other conditions for growth and sugar production.

SUGAR-BEET STAND.

One of the most important factors in sugar-beet production is the stand at harvest time. A perfect stand of beets with the usual width of row and the proper distance of spacing would consist of 30,000 to 40,000 plants to the acre. If each of the beet roots harvested weighed 1 pound, which is below the average in most fields, there should be 15 to 20 tons of roots per acre. As a matter of fact the sugar-beet stands as a rule are only from 50 per cent to 80 per cent perfect, and the average yield of beets in the United States is about 10 tons. Absolutely perfect stands are not to be expected, considering the many factors influencing the stand and the large area in sugar beets, which is now nearly 700,000 acres annually. However, there should be no difficulty in greatly increasing the percentage of stand, thereby increasing the yield per acre. Careful attention has been given to the factor of stand during the last few years, and by actual count in many fields in all parts of the sugar-beet area it has been found that the stand at harvest time very frequently is as low as 50 or 60 per cent. It is very seldom that a field has more than 80 per cent of a perfect stand at harvest time. Many factors influence the stand, some of the most important of which have been carefully studied.

Seed.—The quality of the seed is a primary factor in the stand of sugar beets. All beet seed imported from foreign countries must be up to a certain standard of germination and purity; otherwise it need not be accepted. As a rule sugar-beet seed stored under proper conditions will retain its vitality six or seven years. Usually we have no means of knowing the age of the seed that is shipped to this country, and it is entirely possible that seed imported is sometimes near the limit of its vitality and if held over for one or two years may deteriorate in germinating power. It is customary for sugar companies to retain a part of their seed from year to year to provide against replanting or to take care of belated contracts. All reserved seed as well as new lots should be carefully tested for germination before it is given out to the growers. If the germination of the seed is too low to produce a good stand of beets at the usual rate of planting, either the seed should be discarded entirely or a sufficient quantity of seed should be planted to insure a stand.

With American-grown seed no difficulty should be met in ascertaining its age; in fact, all American-grown seed is utilized within a year or two following its production, so that at present there is no danger of the home-grown seed losing its germinating power before it is planted. All American seed, however, should be tested carefully for germination, for the reason that certain conditions during the process of growth, development, and storage of the seed

may render it weak or nongerminable. One of the most important factors affecting beet seed adversely during its development is the false chinch bug, which occasionally appears in some beet-seed growing localities. These insects infest the beet-seed balls and stalks and by sucking the juice from the plant may prevent the seed from maturing. Careful experiments are now under way, in cooperation with the Bureau of Entomology, looking to the control of this pest. The health and vitality of the beet root when planted for seed is another important factor influencing the quality of the seed. Beet roots that have been weakened by *Phoma* rot or other diseases of the root will sometimes produce seed stalks, and frequently the seed will form; but the plants often die before the seed is mature. If the seed stalks bearing the nonmatured seed are harvested and the seed balls from these stalks are mixed with the matured seed, it is evident that the percentage of germination will be materially reduced. Hot dry winds at the time the seed is forming tend to prevent the seed balls from maturing.

The water supply during the growing season has also a marked effect upon the quality of the seed. If the supply of moisture is too low, especially at the time when the seed is forming, all will not mature and the yield of viable seed will be reduced. In the humid sections where seed is grown we have no direct control over the moisture supply except in so far as we are able to retain the moisture in the soil by proper methods of cultivation. In the irrigated sections wherever water is constantly available the moisture supply is under the control of the grower. It is not advisable to undertake the growing of sugar-beet seed in those irrigated sections where an abundant supply of water is not available for irrigation when needed.

The seed bed.—The condition of the seed bed as a factor influencing sugar-beet stands is of an importance equal to the quality of the seed. In general, the seed bed should be firm and moist and capable of retaining its moisture under all conditions for a considerable period. In order to produce such a seed bed the soil should be thoroughly supplied with humus. The ground should be plowed in the fall, in order that it may catch the winter rain and snow, and the surface should be harrowed as early as possible in the spring, in order to retain as fully as possible the moisture in the soil at that time. The seed bed should be worked from time to time to destroy the weeds that may appear, as they rob the soil of moisture as well as of fertility. Just before planting, the seed bed should be thoroughly worked down and firmed, so that the surface will be uniform in texture and in firmness. If the bed is not uniformly firmed, the drill wheels will sink deeper in some places in the field than in others, with the result that some of the seed will be so deeply covered that the plants will not reach the light or they will be more or less retarded,

producing a spotted or uneven stand. The seed should be drilled into the firm seed bed, so that it will be constantly in contact with the moist soil. (Pl. I, fig. 1.) Poor stands are probably produced oftener by too deep and uneven planting, due to a poorly prepared seed bed, than by any other cause.

Date of planting.—No specific date for planting beet seed can be given, since much depends upon local soil and weather conditions. In general, however, it has been found that the soil should be warm and uniformly moist before the seed is planted, as beet seed will not germinate satisfactorily in a cold, unevenly moistened bed. A few of the stronger plants may come up in the moist spots if the seed bed is not too cold, but the stand will be uneven and far from perfect. It is advisable, therefore, to see that the soil conditions are right before planting. Generally there is a planting period of several weeks during which the seed may be placed in the ground with good results. It has been observed that late plantings will frequently give better results than the very early plantings. It is not advisable to plant in soil that is too dry or too wet. If the soil is too dry and irrigating water is available, it is best to irrigate before planting; if irrigating water is not available and the indications are favorable for rain, it will usually be advisable to wait until rain has fallen. If the ground is too wet when the seed is planted, there is danger of the seed rotting and thereby failing to produce a stand.

Winds.—In some localities wind is an important factor affecting the stand of sugar beets. Aside from the effect of wind upon seed formation, as previously noted, wind is effective in two ways in injuring the stand of beets. If the soil is sandy, strong winds may shift the sand so that the seed is covered too deeply and the young plants can not get through to the light, and if the beet seedlings are up the wind may carry the fine particles of sand against the tender plants with such force that they are destroyed or severely injured. This frequently occurs in level areas where strong winds prevail in early spring. The destructive effect of winds may be overcome, in part at least, by drilling in the seed at right angles to the direction of the prevailing winds and by ridging the ground slightly between the rows.

Crust.—In many sugar-beet localities the soil has a strong tendency to crust if it is moistened and then quickly dried. Showers sometimes fall shortly after the seed is planted, followed by sunshine and drying winds, and in cases where the soil has a tendency to bake a very hard crust will frequently form, which will either prevent the young plants from coming through to the light or will cause a very uneven stand. The crust formed will vary in thickness, depending upon the nature of the soil and the conditions of the weather. If the crust is thin and the young plants have not been

caught in it, a light harrow or a roller will sometimes put the surface in shape so that the plants will break through. If the crust is thick and the plants are embedded in it, there is frequently no remedy except to harrow the ground and replant. A crust may be prevented or greatly retarded by the use of lime and by keeping the ground well supplied with humus.

Blocking and thinning.—A good stand of beets very largely depends upon careful blocking and thinning. Blocking consists of cutting out a portion of the beets by means of a hoe or other suitable implement (Pl. III, fig. 1), usually operated at right angles to the row, leaving the remaining beets in tufts from 8 to 10 inches apart. This should be done while the beets are very small. It is very easy for the careless workman to strike the row at an angle, making the distance between the tufts very much greater, and frequently the tufts themselves are destroyed by careless use of the blocking implement. When the plants have been destroyed, practically nothing can be done to replace them. Transplanting to vacant spaces has not been found practicable on a commercial scale.

The thinning is done by hand and consists in pulling out from each tuft all the plants but one. Careless workers will often destroy or pull out all the plants from the tuft, thereby reducing the stand. The young plants when thinned are frequently left with the dirt removed so that the tender stems are subject to the influence of the rays of the sun, the heat of which sometimes destroys the young plants. The dirt, therefore, should be brought around the plant that is left, thereby protecting it from injury.

Cultivating.—Many otherwise good stands of beets are seriously injured by the cultivator, either by covering the young plants with dirt or by tearing them out. This injury is sometimes due to carelessness and sometimes to accident. Sugar beets are usually cultivated by means of a 4-row cultivator (Plate IV, fig. 1). If by accident or otherwise the cultivator is permitted to shift so that several plants are injured or destroyed in one row, the same number of plants will be injured or removed from each of the four rows. This is a common cause of poor stands in many fields. A few beets cut out of four rows here and there in the field each time the beets are cultivated will have a marked effect upon the final stand and will greatly reduce the yield of beets harvested. The success in operating the cultivator depends upon the condition of the seed bed and upon the animals and the driver, as well as upon the adjustment of the implement. By careful attention upon the part of the driver, nearly all the injury due to cultivation may be avoided, provided the seed bed is in good condition and the drill rows are straight. When the beet leaves cover the ground, as shown in Plate IV, figure 2, the crop is laid by, and no further work is done until the harvest begins.



FIG. 1.—PLANTING SUGAR BEET SEED WITH 4-ROW DRILLS, WHEREBY THE SEED SHOULD BE PLACED AT A UNIFORM DEPTH, IN STRAIGHT ROWS, AND IN A FIRM SEED BED.



FIG. 2.—A FIELD OF SUGAR BEETS, SHOWING FURROW IRRIGATION; EVERY ALTERNATE ROW FURROWED.

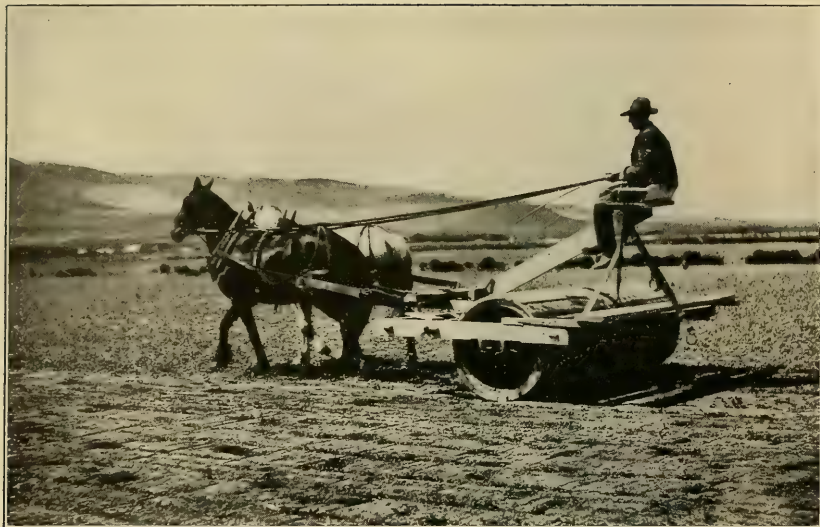


FIG. 1.—THE SMOOTH ROLLER, A USEFUL IMPLEMENT IN PACKING THE SEED BED BEFORE AND AFTER PLANTING.



FIG. 2.—THE CORRUGATED ROLLER, AN IMPLEMENT WHICH BREAKS THE CRUST AND RIDGES THE GROUND AGAINST WIND EFFECT.



FIG. 1.—BLOCKING AND THINNING SUGAR BEETS, AN OPERATION THAT MUST BE PERFORMED BY HAND AS SOON AS THE BEETS ARE LARGE ENOUGH.



FIG. 2.—FLOODING A FIELD OF SUGAR BEETS, A METHOD OF IRRIGATION WHICH DESTROYS THE STAND OF BEETS AND INJURES THE SOIL.



FIG. 1.—A 4-ROW CULTIVATOR, WHICH IF NOT CAREFULLY USED MAY DESTROY A GOOD STAND OF BEETS.



FIG. 2.—A FIELD OF SUGAR BEETS WHOSE TOPS COMPLETELY COVER THE GROUND, AT WHICH STAGE THE CROP MAY BE LAID BY.

Diseases affecting stand.—One of the common agencies affecting the stand of sugar beets is disease. Nearly all of the sugar-beet diseases are due to parasitic organisms. One of the most serious affecting the stand is the damping-off of the young beets. Later in the season root-rot does considerable damage in some localities. Leaf-spot frequently injures the beets and reduces the tonnage, but does not often destroy the stand. All fungous diseases may be greatly reduced or entirely controlled by proper cultural methods, including the proper rotation of crops. There are several diseases which sometimes destroy entire fields. The disease known as "curly-top" belongs to the group. This is an obscure disease, the cause of which is not definitely known. The Office of Sugar-Plant Investigations in cooperation with the Bureau of Entomology is making an earnest effort to determine the cause of this disease and to find a practical means for its control. Another serious pest affecting the stand of beets is the sugar-beet nematode. The nematode first appears in a field here and there, destroying a few beets. From year to year this becomes more marked if beets are grown continuously in the infested fields, and eventually the whole field will be affected and a worthless crop will result. The Office of Sugar-Plant Investigations in cooperation with the Office of Agricultural Technology is carrying on extensive experiments in all areas infested with the sugar-beet nematode, with a view to controlling this pest in a practical way, so that profitable crops of beets may be grown in spite of the nematode. For a further discussion of sugar-beet diseases, see pages 44 to 47.

Insects affecting stand.—There are several insects affecting the stand of sugar beets. The most common during the early stages of the beet are wireworms and cutworms. The latter usually cut off the root at some distance below the ground. As a result the plant dies or produces a very short root. Sometimes the cutworms destroy beets here and there in the field, but when the pests are numerous the entire stand may be destroyed, necessitating replanting in order to produce a crop. White grubs also are serious pests. They are the larvæ of the May and June beetles. They occur frequently in sod ground and are to be expected in beet fields where beets follow sod. Later in the season army worms and related pests frequently do considerable damage. Even if the stand is not seriously injured by the pests the tonnage is greatly reduced. For a further discussion of insect pests affecting sugar beets, see pages 47 and 48. For a list of publications relating to sugar-beet diseases and insects, see pages 55 and 56.

Rodents affecting stand.—In some localities ground squirrels and other rodents are a serious menace to the sugar-beet crop. They feed upon the beets from the seedling to the mature stage, but do most of their damage when the beets are about half grown. They some-

times make serious inroads upon the stand of beets. These pests may be destroyed by the use of poison or by trapping.

WATER.

Excess or deficiency of water may be a limiting factor in sugar-beet production.

Precipitation.—In the humid sections of the sugar-beet area beet growers depend upon rainfall and snow for the necessary supply of soil moisture. Usually the snow and the spring rains put the soil in good condition for planting, and the summer rains keep the crops growing until the end of the season. Whether the precipitation will furnish an excessive amount of moisture for the soil will depend upon soil conditions as well as upon the amount of precipitation. For uniform soil conditions, however, the consideration of precipitation is of vital importance in the growing of sugar beets. Excessive precipitation may be detrimental in two ways: (1) By preventing a proper preparation of the seed bed, and (2) by saturating the soil to such an extent that the air is excluded from the plant roots and the proper growth of the plants thereby prevented. Likewise, a deficiency of precipitation may make a proper preparation of the seed bed impossible, or it may put the seed bed in such condition that the germination of the seed or the subsequent growth of the plants may be impaired. Excessive precipitation may be remedied under certain conditions by a proper system of drainage. (See pp. 21–23.) The lack of moisture may be remedied in part (1) by putting the proposed seed bed in a proper condition to catch and hold the fall and winter moisture; (2) by subsequent cultivation, whereby a mulch is formed on the surface of the field, thereby retarding evaporation; and (3) by supplying the soil with a suitable amount of humus.

Irrigation.—The use of irrigating water is theoretically simple, but its practical application is very complex, calling for a knowledge of plant growth and soil requirements based upon experience and good judgment. It is one of the most important factors in sugar-beet production in the semiarid regions. Good crops are sometimes ruined by a lack of knowledge of the water requirements of plants and by want of experience in applying the water.

There are four sources from which irrigating water may be obtained, namely, from reservoirs, direct from streams, from flowing wells, and by pumping. A reservoir is a storage place in which an excess of water due to melting snows or from other sources may be stored for future use. Stream irrigation implies either a continuous or an intermittent flow of water in a river bed which may be drawn upon when needed. Pump irrigation is practicable when the sub-

surface water is present in sufficient quantity and at a shallow enough depth to supply the necessary water for crop production at a reasonable cost.

Reservoirs are either individual storage places which supply moisture for a single farm or part of a farm or they may be community enterprises operated by the landowners or by an irrigating company. Community reservoirs are sometimes filled direct from permanent streams and sometimes they are filled during freshets, while individual reservoirs are frequently supplied with water by pumping; in this manner pump irrigation may be direct or indirect. By direct irrigation the water is pumped into the ditches or laterals and spread at once upon the fields; by indirect irrigation the water is pumped into a reservoir, from which it is distributed upon the field when needed. There are difficulties to overcome in each of the methods of irrigation mentioned. In utilizing water from a community reservoir it is necessary for all farmers under the ditch from this reservoir to use the water at a time agreed upon by the majority of the users, regardless of the requirements of all of the crops to be watered. In case the water is not used by one or more farmers when the reservoir is open, they must await the next opening of the reservoir, which may be several weeks later, regardless of the injury that the lack of water may cause to their crops. The reservoir can not be opened at the will and pleasure of each water user. To do so would cause a great waste of water, which is often of greater value than the land itself.

Water from a community reservoir is usually prorated and measured to each farmer so that he is able to obtain only his share; likewise, in using water from a stream in which the supply is limited it is prorated and measured, and irrigation must cease when the allotted number of acre-feet has passed through the gate, regardless of the crop requirements. If the pumping plant is a community plant practically the same regulations obtain as in the case of the community reservoir, that is, each farmer entitled to water must use it at a definite time agreed upon by a majority of the users, whether his crop needs water or not. It would, of course, be too expensive to operate the pumping plant for a limited number of farmers whose crops were not in need of water at the regular irrigating period. The individual plant is usually more satisfactory from the standpoint that water may be available when needed. The expense, however, of installing and operating individual pumping plants has frequently been beyond the means of many of the farmers in a given community. It is apparent, therefore, that the water supply for irrigating a sufficiently large area to insure the growing of the necessary acreage to enable a sugar mill to operate successfully is frequently the deciding factor in the growing of sugar beets. The prob-

lem of water supply should be considered carefully before any large sum of money is expended in the erection of a mill in any locality in which irrigation is necessary.

If the water supply in a given area will insure the growing of only 5,000 acres of sugar beets annually under proper crop rotation and under other conditions favorable to sugar-beet culture, it would not be advisable to build a mill having a capacity greater than 500 tons per day. It frequently happens that a large part of the water used for irrigating purposes is wasted either by badly constructed ditches or by improper methods of irrigating. Ditches are improperly constructed when they allow an excessive amount of seepage or when they are so easily clogged that they overflow. Under the methods in practice it is sometimes impossible to avoid using water on certain fields when it is really not needed. Occasionally the water is turned on from the reservoir or the community pumping plant is put in operation before the water is actually needed by any of the growers. Much can be done to delay the first irrigation and to extend the time between irrigations by proper preparation of the seed bed and by proper cultivation. In most irrigated areas the actual water supply is limited, and in order to meet the crop requirements as nearly as practicable there should be no waste of water beyond the unavoidable losses due to seepage and evaporation.

Methods of irrigation.—There are two general methods of irrigating sugar beets, namely, by flooding, as shown in Plate III, figure 2, and by the furrow method, as shown in Plate I, figure 2. The first is generally detrimental to sugar-beet production and is wasteful of water. In flooding the entire surface of the field, more water is used than would be used by the furrow method. There is a much larger surface for evaporation. The air supply is cut off from the beet roots, and as soon as the ground begins to dry after a flood irrigation the surface frequently forms a crust, which further cuts off the air supply, promotes evaporation, and incases the beet plants in such a way that it is very difficult to cultivate or otherwise work the plants without doing some damage. It is argued that flood irrigation is necessary in certain sections where the slope of the land is slight, but it is seldom the case that the slope is not sufficient to enable the careful irrigator to use the furrow method, especially if proper laterals and cross ditches are used. In using the furrow method of irrigation a furrow is made between the rows of beets or between each alternate row and the next, as shown in Plate I, figure 2, and frequently this furrow is smoothed or sledged out by an implement, as shown in Plate V, figure 1, which is drawn lengthwise through the furrow, leaving its surface smooth and well adapted to carrying the water. The water should be turned into these furrows and should be confined to them entirely, without flooding the surface

around the beets. The water should be allowed to flow until the soil is thoroughly wet. The head of water which is used in furrow irrigation must not be too large, as shown in Plate III, figure 2. The size of the head must be governed by the slope of the land, by the nature of the soil, and by the number of furrows that can be supplied at one time.

Leveling.—In order that irrigation may be properly done the field must be carefully leveled, as shown in Plate V, figure 2. This is frequently a limiting factor on many fields and occasionally in an entire community. The lack of success in at least one sugar-beet area is due primarily to the failure of the growers to level the ground properly. It usually requires several years to level a field properly for furrow irrigation, for the reason that the depressions that are filled during the first effort to level the field will usually settle and still leave slight depressions, while the higher points from which the soil was removed to make the fills do not settle and an unevenness results. If the leveling process is repeated for two or three years the ground is generally sufficiently level to admit of furrow irrigation. If the ground is very uneven the Fresno scraper may often be used to good advantage. In some localities the surface of the soil is by nature sufficiently level to admit of proper irrigation. In other sections the slopes are sufficiently long and the source of the water supply so high that it can be carried to the highest point and distributed over large areas without going to the expense of leveling the ground. In the process of leveling, the better surface soil is removed from the high point and carried to the depression. It is then necessary to improve the areas from which the better soil has been removed, either by the use of stable manure or a leguminous crop. Sometimes several years are required to make a leveled field uniform in fertility as well as in firmness of surface.

A very coarse soil, especially if it has a porous subsoil, is irrigated with great difficulty, and frequently much time and money are wasted in leveling such lands, as they are not adapted to the growing of sugar beets or other intensively cultivated crops.

DRAINAGE.

Drainage has an important bearing upon sugar-beet growing in general, as well as upon the production of other farm crops. Large areas of land that are now too wet to be cultivated could be put under tillage and produce good crops if properly drained. Other large areas now under cultivation are in many instances becoming water-logged, especially in the irrigated sections, and will soon be unfit for crop production unless they are drained. In some instances the further expansion of the sugar-beet acreage is limited to the bringing in of areas through drainage.

Natural drainage.—Fortunately a large part of the tillable area now devoted to sugar-beet culture has a natural drainage. This may be due to one of several conditions.

(1) The surface of the ground may be sufficiently rolling to drain naturally. In some instances the slope is so great that the water passes off too quickly, and consequently the land is unproductive because of excessive surface drainage.

(2) Certain areas have a natural drainage due to a sloping subsoil. As previously noted, some areas have a subsoil that is more or less impervious to water. If the impervious subsoil is sloping, the water falling upon the surface soil will pass through to the subsoil and gradually disappear along the sloping subsoil. In this case natural drainage is satisfactory and needs no particular attention provided the impervious subsoil is not too near or too far from the surface, and provided further that there is a natural outlet, so that the water will not eventually back up along the slope or incline of the subsoil.

(3) The natural drainage accomplished by means of a porous subsoil has been already noted. There are localities in which the subsoil is so porous that it is almost impossible to hold sufficient water in the seed and root beds to produce a crop of beets. There are therefore localities in which the natural drainage is of such a nature, either through a lack of moisture or through an excess of water, that natural drainage constitutes a limiting factor in sugar-beet production.

On the other hand, there are areas and fields in which artificial drainage must be practiced in order to put the soil in condition for sugar-beet production. Several systems of artificial drainage are in general use.

The open ditch.—An open ditch constitutes one of the methods by which this limiting factor of excessive moisture is removed. It is the least expensive method of providing artificial drainage, especially from the standpoint of labor and material involved. However, considerable tillable ground is lost through the construction of open ditches. This loss is due to the space occupied by the ditch and by the ditch bank. In constructing an open ditch these points should be kept in mind, so that the least possible loss of tillable area will result. The open ditch constitutes a barrier which can not readily be crossed in the usual farming operations. It is advisable, wherever practicable, to construct these ditches along the edges of the field, along roadsides, and in places where they will interfere least with the farming operations. Sometimes it is necessary to cross the fields with ditches in order to drain the soil properly; in such cases the fields and ditches should be so laid out that the ditches

will run lengthwise of the field, thereby avoiding the crossing of the ditch in the usual farming operations. The size and depth of the open ditch will depend upon the length and fall of the ditch, the location of the subsoil, the amount of water to be carried, and the position of the outlet. It should always be deep enough to prevent any interference of the water table with the crop to be grown.

The blind ditch.—The most satisfactory method of artificial drainage is the blind ditch. In the construction of this ditch tile is used most commonly. Many fields that otherwise would not yield profitable crops have been reclaimed by the blind ditch. These ditches should be laid out very carefully with reference to direction, depth, and slope, so that the entire area under consideration will be drained thoroughly. The size of the tile is very important. Tiles that are too small must never be used. This is false economy, and it frequently results in added expense in that the small tiles must be taken up and replaced with larger ones. The tile should be large enough to carry off the water quickly in times of excessive rainfall, deep enough not to be disturbed by the plow or other implements, and laid so carefully that the ends will fit against each other evenly and a gentle and continuous fall provided, without depression or elevation. The outlet of the blind ditch should be kept open that the water may flow freely.

SEEPAGE.

Seepage is closely related to drainage. Many fields or areas that otherwise might be profitable for crop production are rendered useless by seepage. This is especially noticeable in those areas where irrigation is practiced. Seepage is detrimental to the soil in several ways: (1) As a loss of water, especially in cases where water has been stored for irrigating purposes, and (2) through a loss of the use of the land, either because the soil is too wet for crop production or because of the accumulation of soluble minerals which are brought to the surface through seepage. The injurious soluble minerals usually are known as alkali.

Seepage from streams.—Some streams are so located naturally that a portion of the water seeps out into the adjacent soil, forming marshes or waste places due to excessive moisture; this is especially true where the fields adjacent to the stream are low, level, or underlain with an impervious subsoil. The nature of the bank of the stream is of importance in this connection. If the overflow at flood time is prevented by the construction of dikes the land may be made productive by drainage. Usually these marshlands when drained are very fertile and produce good crops, though they are not always the best for sugar-beet production, since they sometimes produce large roots low in sugar.

Seepage from ditches.—It is sometimes necessary to construct irrigating ditches higher than the surrounding area in order to carry the water across low places or to carry it long distances. It is very common for the water to seep through the ditch bank in such cases and to saturate the surrounding fields, especially if the soil in those fields has a high water-holding capacity. Ditches constructed of clay or other close-textured material seep to a less extent than ditches constructed of sandy or other porous material. In the case of sandy ditches the holding capacity may be increased very greatly by oiling the surface of the ditch with crude oil; this can be applied economically only in those localities not far removed from the source of oil supply. Where the oil is available it may be spread over the inner surface of the ditch when the ditch is empty and should be allowed to soak into the soil. A second or even a third application of the oil will improve the condition of the ditch. Ditches treated in this manner will carry water with almost no loss, and when the work is done properly the oiled surface will frequently last for several years. If the oil is spread over the ditch bank, weed growth will be prevented, or at least decidedly retarded. There is always some seepage from the ordinary untreated earth ditch, and the amount of damage done by this seepage will depend upon the nature of the ditch and the soil of the adjacent fields. The seeped areas may sometimes be rendered tillable by drainage.

Seepage from earth reservoirs.—The area of land damaged by seepage from earth reservoirs is less than that from ditches, but the total is considerable and is usually progressive; that is, a small area first appears to be water-logged and this gradually increases from year to year until large areas involving fields and sometimes entire farms are destroyed. Seepage from reservoirs will depend upon the construction of the reservoir and upon the nature of the surrounding country. Reservoirs are sometimes constructed in mountainous areas for the purpose of catching and storing flood waters due to melting snows. Generally the location of these reservoirs is such that no damage is done to the soil through seepage; the only loss in such cases is caused by the quantity of water which seeps away and becomes unavailable for irrigation purposes. In other instances reservoirs are constructed of cement, which is nearly impervious to water, and consequently little or no loss from seepage results. The serious injury due to seepage from reservoirs takes place in those localities in which the reservoirs are constructed entirely or in part of earth and in which the surrounding country is composed of tillable land; in such cases the loss due to seepage is sometimes of considerable importance.

Alkali.—As already indicated, one of the serious results of seepage is the accumulation of alkali in the surface soil. In such cases

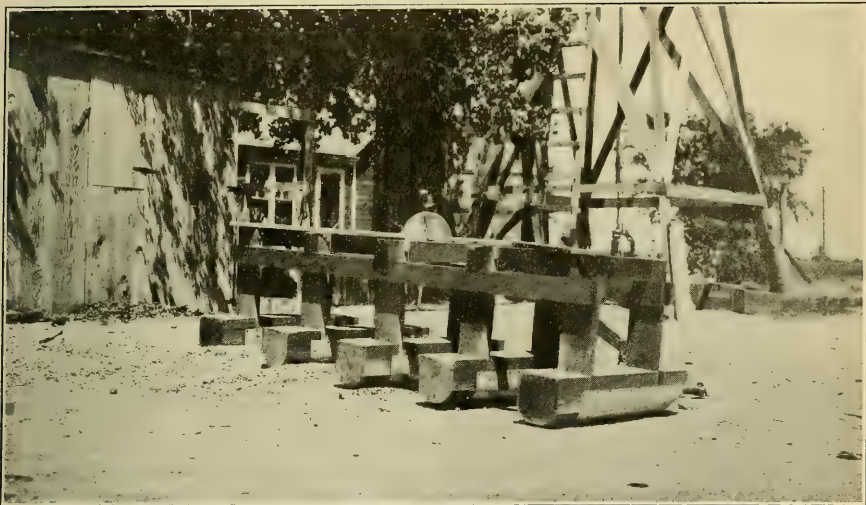


FIG. 1.—A SLEDDING IMPLEMENT USED IN SMOOTHING IRRIGATING FURROWS IN SUGAR-BEET FIELDS, BEING SOMETIMES HELPFUL IN DISTRIBUTING THE WATER.



FIG. 2.—A FLOAT USED IN LEVELING THE SEED BED FOR SUGAR BEETS.



FIG. 1.—PREPARING LAND FOR SUGAR BEETS BY PLOWING UNDER A CROP OF ALFALFA, ONE OF THE BEST GREEN FERTILIZERS WHEN THUS TREATED IN THE FALL.

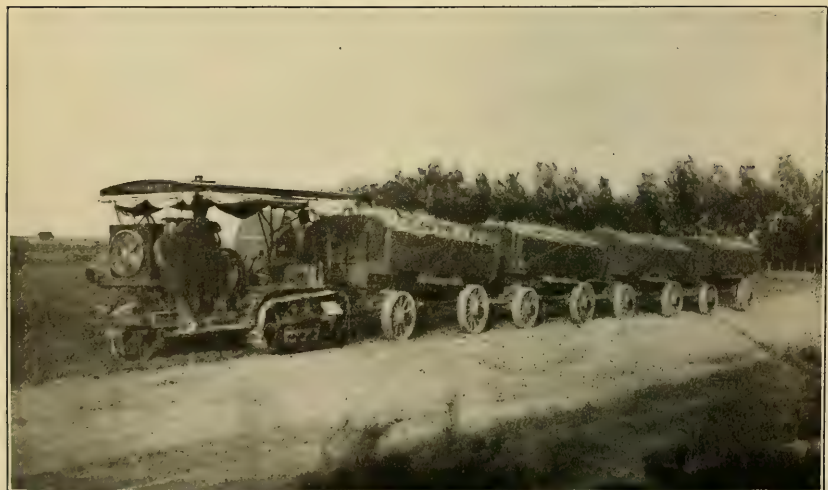


FIG. 2.—HAULING SUGAR BEETS TO THE MILL, THE COST BEING GREATLY REDUCED BY GOOD ROADS.

there must be more or less alkali dissolved in the water. As this water rises to the surface of the soil it brings with it the salts held in solution. After the water evaporates from the surface of the soil the alkali remains, and it may eventually accumulate to such an extent that crop production is greatly reduced or rendered entirely impossible. This condition is a limiting factor in the production of sugar beets as well as other crops in certain portions of the sugar-beet area. The sugar beet is one of the most alkali resistant of our farm crops, but even with this plant the limit of endurance is sometimes reached or exceeded, and beet growing becomes unprofitable. Alkali in the seed bed is especially troublesome, since the young plants are very tender and therefore susceptible to this and other adverse conditions. If the beet plants are well started before the alkali accumulates in the surface soil, much less damage will be done, as the subsequent growth of the plants is less affected by the same amount of alkali. The alkalinity of a soil may be reduced by the use of irrigation water, provided the irrigating water is comparatively free from alkali and a satisfactory drainage system has been established.

FERTILITY.

Elements of plant growth.—By fertility in this connection is meant the ability of the soil to produce a good crop. The difference between a rich soil and a fertile soil should be kept in mind—that is, a soil is rich if it contains a considerable quantity of each of the elements required by the plant in the process of growth. Unless, however, these elements are available to the plant and the physical conditions of the soil are such as to promote plant growth, the soil can not be said to be fertile. If a single element required by the plant, though present, is not soluble, this condition will render the soil infertile. In order that an element may be available to the plant, it must be soluble, and it must dissolve rapidly enough to supply the plant with that particular element as rapidly as the plant requires it. Certain elements are always available when present; other elements must be acted upon by certain substances under certain conditions in order to become available or soluble. It is apparent, therefore, that fertility is one of the limiting factors in the production of sugar beets as well as of other crops.

The sugar beet requires the same elements of plant food that are required by other field crops, but in slightly different proportions; for example, a 10-ton crop of sugar beets (which is approximately the average yield for the United States) will require about 30 pounds of nitrogen, 14 pounds of phosphoric acid, and 71 pounds of potash; a wheat crop, yielding 20 bushels per acre, will require 41 pounds of nitrogen, about 13 pounds of phosphoric acid, and 17 pounds of

potash; a corn crop, yielding 40 bushels of ears to the acre, will require 56 pounds of nitrogen, 21 pounds of phosphoric acid, and 23 pounds of potash; clover yielding 2 tons of hay per acre requires 83 pounds of nitrogen, 18 pounds of phosphoric acid, and 88 pounds of potash. These elements are required by all field crops, and, in addition to these, seven other elements are required in much smaller quantities. These elements are always present in agricultural soils in larger or smaller quantities. The two questions, therefore, with regard to soil fertility, so far as the composition of the soil is concerned, are whether the required elements are present in sufficient quantity to produce the desired crop and whether the elements are available or soluble in such quantity and at such time during the growing season as the plant requires. In addition to the presence of these elements, as indicated above, the soil must be in proper physical condition to promote plant growth in order to be fertile. In the production of sugar beets a moderately fertile soil is required. If the soil is lacking in fertility the roots may be too small to produce sufficient tonnage to make the crop profitable to the grower. Under ordinary farm conditions there is little danger of the soil being too fertile for satisfactory beet growing. Occasionally spots are so fertile that large roots low in sugar are produced, as, for example, an old feed lot, a barnyard which has been turned into a portion of the field, or a spot where an old straw stack has been left to decay. These areas are small and insignificant when compared with the total sugar-beet acreage in the United States, but they sometimes have an important bearing upon the results on an individual farm, especially where the sugar-beet acreage on that particular farm is small. The greatest danger from the standpoint of fertility arises from the lack of those physical conditions or the absence of available plant foods to produce large yields. The principal problem, therefore, in this connection lies in the improvement of the fertility of the soil. Soils may be rendered infertile through natural causes, such as leaching, and through artificial causes, such as single cropping, improper crop rotation, and the improper proportion of live stock to crop production. One of the principal methods that may be employed to increase soil fertility is the addition of humus to the soil, either in the form of stable manure or of green crops plowed under.

Stable manure.—One of the most satisfactory methods of supplying humus to the soil is the proper use of stable manure. A close relation should exist between the number of live stock on the sugar-beet farm and the acreage under cultivation. Studies in practically all parts of the sugar-beet area indicate that the number of live stock on most farms is too small for the most profitable production of crops and is usually below the possibilities in both live-stock and crop production when we consider the number of acres under culti-

vation and the satisfactory crops that the tillable area is capable of producing when properly fertilized and tilled. Furthermore, a considerable portion of the stable manure produced on most sugar-beet farms is wasted or rendered only partially effective either by not giving it proper care or by the method in which it is handled in connection with crop production. In addition to the humus contained in stable manure considerable quantities of plant food are present, which if properly handled add to the fertility of the soil. This plant food is largely soluble; consequently the leaching process to which the stable manure is in most cases subjected, owing to the fact that it is usually exposed to rains and snows, frequently causes much of the fertility to be lost. Again, stable manure is often spread upon the fields and left exposed to the weather, until a large part of the volatile plant foods have passed off into the atmosphere. Much of the nitrogen is often lost in this manner. The best results in utilizing stable manure in connection with sugar-beet production are obtained by applying the manure to the crop preceding the beet crop; this allows the manure to be thoroughly worked into the soil. It is a common practice in many localities where manure spreaders are not used to haul the manure from the feed yard or stable at times when there is no urgent work to be done and to dump it in piles, to be spread at some convenient time before the ground is plowed. This is a wasteful method, especially if the piles are left for some days or weeks without spreading, often resulting in much loss of valuable material through leaching. However, this method is preferable to spreading the manure and leaving it on the surface of the ground exposed to the action of the sun and wind. If the manure is spread and the ground can not be plowed immediately, it should be disked whenever practicable; that is, if the ground is not frozen. Fortunately the manure spreader is becoming more and more common, and where the number of live stock on the farm warrants it there is probably no other implement of greater value to the farmer. The full value of the spreader is not realized, however, unless the manure is plowed under or worked into the soil immediately after spreading.

Green crops.—Green crops plowed under provide another source of humus for soil improvement. Any vegetable matter plowed under and worked into the soil will add humus, though certain crops are more valuable for this purpose than others because of the plant food as well as the vegetable matter which they contain. The so-called leguminous crops, such as peas, beans, clover, and alfalfa, are among the best for supplying humus to the soil. These crops should be plowed under in the fall, so that they will have abundant opportunity to decay before the growing season begins the following year. In irrigated countries the ground should be irrigated thoroughly, if necessary, before plowing, so that there will be sufficient moisture

in the soil to bring about the desired change in the crop that was plowed under. In the case of such crops as clover and alfalfa usually one or more cuttings are made for hay, and the later growth is plowed under when it has attained the height of 1 to 1½ feet, as shown in Plate VI, figure 1. If cowpeas are used for green manure, they are usually planted in midsummer and plowed under when they have attained their normal growth in the fall. All crops, when used for this purpose, should be plowed under while they are still green.

If for any reason a leguminous crop can not be grown for green manure, other crops, such as oats, rye, barley, or even sorghum, may be used. Maintaining the humus in the soil is more difficult in the irrigated than in the humid sections of the country. The climatic conditions, especially the hot winds, seem to have a decidedly reducing effect upon the quantity of humus in the soil. Humus in irrigated sections is doubly important, since it is necessary not only in maintaining and improving soil fertility, but it also has a decided advantage in increasing the water-holding capacity of the soil.

The green crops will add little material that was not already in the soil. They may, however, bring up the elements required for plant growth from considerable depths and, when plowed under, deposit them in soluble form in the surface soil. For this reason deep-rooted crops are to be preferred to the shallow-rooted ones. At any rate, some deep-rooted crops should be included in each rotation system. The green crops, especially the legumes, may increase to some extent the nitrogen content of the soil. Stable manure, if applied in sufficient quantity, will supply at least a part of the necessary plant foods besides adding some humus to the soil.

Commercial fertilizers.—If the required elements are not present in the soil, or if those present can not be made readily available, they should be supplied in the form of so-called commercial fertilizers. The composition of the fertilizer used will depend upon the requirements of the crop to be grown and upon the condition of the soil which is to be used for crop production. From the figures given above it is apparent that a sugar-beet or clover crop should have an abundant supply of potash, while for a wheat or corn crop special attention should be given to the nitrogen supply. A complete fertilizer consists of nitrogen, phosphoric acid, and potash. Compounds containing these elements are mixed in different proportions for different crops and for different soil requirements. It frequently appears that a complete fertilizer is not required. For example, there may be present in the soil an abundant supply of available potash, while the supply of nitrogen and phosphoric acid is deficient. In that case a fertilizer containing the required amount of nitrogen and phosphoric acid only should be applied. Under certain conditions

commercial fertilizers do not seem to be effective. This may be due to the physical condition of the soil. The greatest benefits are obtained from commercial fertilizers when the soil is well supplied with humus. There should, of course, be a sufficient supply of moisture in the soil to dissolve and hold in solution the plant foods that are already present or that may be supplied in the form of a commercial fertilizer. The benefits arising from the use of fertilizers, whether stable manure, green crops, or mineral compounds, are frequently noticeable over a period of several years; hence in estimating the value of a fertilizer the results of several seasons' crops should be taken into account.

CROP ROTATION.

Occasionally a farm is found on which beets are grown on the same field year after year. While this seems to give satisfactory results for a time in some instances, it is in general a poor method and one that can not be recommended, since it tends to encourage the development of certain sugar-beet pests which eventually render the crop unprofitable. The rotation practiced in the various sugar-beet areas must necessarily depend upon the crops that do best in these several localities, as well as upon the other crop and live-stock requirements of the farm. In some areas, for example, the Irish potato is a profitable crop and forms an important link in a system of rotation with sugar beets. In other areas the Irish potato is not successful, and in such sections it would be a waste of time and money to undertake to utilize it in rotation with sugar beets. Again, there are areas in which the muskmelon is very satisfactory and rotates well with sugar beets or other crops; in other parts of the sugar-beet territory the muskmelon can not be grown with success. In planning the rotations, therefore, one must have in mind not only the crops that will rotate well with sugar beets, but also the success of those crops independently. The grower must also consider the practicability of handling such crops from the standpoint of his returns; for example, in some sugar-beet areas alfalfa gives good yields, but because the hauls are so long the value of the alfalfa under normal conditions is not sufficient to pay the transportation charges and leave a reasonable profit. Therefore, unless there is an abundance of live stock to utilize the alfalfa locally or unless it is needed as a soil improver, it is not a satisfactory rotation crop in certain localities in spite of the fact that it produces satisfactory yields. Our studies of the various sugar-beet sections indicate that live stock is an important factor in crop rotation on the sugar-beet farms. As already indicated, certain crops can be grown to advantage if there is an abundance of live stock to utilize them. Even if certain crops could be sold from the farm at a reasonable return above the cost of produc-

tion, it would be poor policy to sell them, for the reason that by so doing a large amount of plant food would be shipped away. Live stock, if properly handled, enable the farmer to keep a larger proportion of the plant foods on the farm than could be done if the crops themselves were removed. Feeding the crops on the farm is the best practice, and will generally yield the largest returns per unit of land and per unit of labor, especially if the proper relations between crops, live stock, land area, and labor are established. It is apparent, therefore, that several objects may be accomplished by proper crop rotation, all of which must be kept in mind in order to reap the greatest returns from the sugar-beet farm.

Effect on the soil.—As has been previously noted, all plants require certain plant foods, and these elements are utilized by different plants in different proportions. The rotation of crops insures a better utilization of these plant foods than can be obtained by growing a single crop. Certain crops are deep rooted while others are more shallow. The deep-rooted crops tend to stir the soil to a greater depth and in this way make the plant foods more readily available for the shallow-feeding crops. Certain crops aid in the production of certain plant foods, as, for example, the leguminous crops store nitrogen, which is rendered available to the other crops grown in rotation with the legumes. Again, certain crops require more or less cultivation, as is the case with sugar beets. This stirring of the soil tends to expose the plant foods to the action of the elements, thereby rendering the mineral material available for the use of the beet plants and the plants of succeeding crops.

Relation of pests to crop rotation.—The rotation of crops tends to reduce or to destroy plant pests which depend upon certain plants for their existence. As is well known, some plant pests live and thrive only on certain plants. If these plants are grown year after year in the same field, they furnish favorable breeding conditions for the propagation and increase of these pests. By changing to other crops, plants upon which the pests can not live or upon which they do not thrive may be grown and the pests thereby destroyed or reduced to a minimum. Frequently the pests have resistant forms or stages in which they can exist in a dormant condition for several years, as is notably true of the brown-cyst stage of the sugar-beet nematode and the resting-spore stage of certain fungi. In such cases it is necessary to plan the rotations with a view to starving out these pests. To do this the rotations must be of such a length that crops upon which these pests can not thrive may be grown for several years in succession. In some cases other methods must be resorted to in order to control the destructive pests, but a large

number of the sugar-beet pests, including some of the fungi and bacteria as well as insect pests, may be controlled by crop rotation.

Effect of sugar beets upon other crops.—As a rule, the effect of sugar beets upon succeeding crops is beneficial. This is especially true of the small grains; that is, small grains grown after sugar beets will almost invariably produce larger yields than when these grains are made to follow other crops. The sugar beet does not produce plant foods, as do the legumes, but owing to the long roots and the methods of cultivation employed in growing and harvesting the beet crop the soil is put in splendid tilth, thereby forming good seed and root beds for the crops that follow the beets. These indirect benefits to the growers are important in considering the advisability of growing sugar beets and should be estimated at their just value. These indirect benefits due to sugar-beet growing have only a remote bearing upon the price paid for beets and upon the price of sugar. They should, however, be considered in figuring the profits derived from sugar-beet culture.

COMPETING CROPS.

Crops grown in competition with sugar beets may or may not be suitable for rotation with sugar beets. By competing crops is meant those crops grown in sugar-beet areas which appear to be more profitable or more easily produced, or for some reason are so favored by the farmer that he may possibly prefer them to sugar beets. Some of the competing crops do not lend themselves readily to a rotation with sugar beets. In such cases the competing crops may be a limiting factor in sugar-beet production on an individual farm, or if the crop is a general one it may be a limiting factor in sugar-beet production in a given community. A crop may compete with sugar beets because of its market price, because of the small amount of labor involved in its production, because of the peculiar fitness of the soil for the growing of that crop, because of local market conditions, or because it fits more closely the requirements of the individual farms than any other crop. The competing crops in the sugar-beet sections are such as beans, tobacco, potatoes, muskmelons, alfalfa, and grains. Other crops may temporarily be competing with sugar beets and some of those mentioned may for local or other reasons temporarily cease to be competing crops. Most of the competing crops may form with sugar beets a satisfactory crop-rotation system in one or more of the recognized sugar-beet areas.

Beans.—In our farm-to-farm survey we have found beans a competing crop in several localities, and under existing conditions it is one of the strongest competitors. This crop is easily produced and under present conditions it is bringing a fair return to the farmer for the labor and money invested. In some of the areas studied

beans have ceased to be a competing crop because of local conditions, the chief of which is the presence of certain bean diseases. It was believed that beans could follow beans profitably in the same field for a number of years, but this crop, like all others, is more satisfactory in the long run when grown in proper rotation with other crops. As in the case of sugar beets, continuous cropping with beans has enabled certain diseases of the bean to be propagated from year to year, thereby becoming more widespread and more destructive, until bean production in certain areas is no longer profitable. If properly handled beans should be a good crop to rotate with sugar beets. They should not compete with the sugar beet to the exclusion of the latter, for the reasons above stated. The diseases affecting sugar beets and beans are for the most part very different, and for this reason these crops rotate well together. Again, the sugar beet leaves the ground in good condition for the production of the bean crop. If the beet crop has been properly handled the weeds are eliminated, and in this respect the field is left in a good condition for beans. If beans are planted on a field filled with weed seed, either considerable time and labor must be spent in destroying the weeds or they must be allowed to grow to the detriment of the bean crop and be an annoyance and added expense when the beans are harvested. Furthermore, sugar beets leave the ground in good physical condition for a bean crop; on the other hand, if beans precede beets they will leave the ground in good condition for the sugar beets. The order of rotation, therefore, with these crops is not particularly important.

Tobacco.—Tobacco is not generally grown in the sugar-beet areas, but there are a few localities in which tobacco and sugar beets are both produced. While the tobacco crop is expensive to handle, the returns under favorable conditions make it a strong competitor. The methods used in growing tobacco do not usually lend themselves well to crop rotation; for example, tobacco fields are usually heavily fertilized with commercial fertilizers. Part of the results to be expected from these fertilizers should be apparent during the second or even the third year after it is applied. Owing to this large expense growers usually expect to use the same field for the tobacco crop for a series of years, consequently it does not admit of ordinary crop rotation. Again, the tobacco crop requires a large amount of labor, some of which conflicts with the labor necessary for sugar-beet production. If, however, a farmer can obtain sufficient labor to handle both crops there should be no serious difficulty in producing both sugar beets and tobacco, especially if both of these crops are produced on comparatively small areas on the individual farm. It may be found, also, that these crops will rotate one with the other to the advantage of both.

Potatoes.—In certain areas studied, the potato under present conditions is one of the strongest competing crops with sugar beets. Where these crops are grown in rotation, however, the results, from the standpoint of yield, are satisfactory. Unfortunately, certain diseases affecting potatoes attack sugar beets also; this is notably true of the scab. With the price of potatoes higher than for many years past, the tendency in the especially good potato area has been to increase the potato acreage and diminish the sugar-beet acreage correspondingly. The chief danger is that when the potato crop is harvested the price may be lower and the results somewhat disappointing. It should be noted in this connection that the prices paid for sugar beets are in practically all cases fixed before the seed is planted. The returns from this crop, therefore, depend only upon the yield and quality of the beets produced. As already indicated, sugar beets and potatoes form a part of a satisfactory rotation, but neither of these crops should immediately succeed or follow the other because of the diseases that are common to both plants. There should be one or two years of intervening crops, such as small grains or alfalfa.

Alfalfa.—In some localities studied, alfalfa has appeared to be a strong competing crop with sugar beets. This is true in part because of the tendency to leave alfalfa sod without breaking for a number of years, thereby making a very long rotation or, in some cases, what amounts to no rotation; for example, certain areas have been found in which alfalfa has remained undisturbed in some fields for upward of 20 years. Alfalfa is an inexpensive crop to produce, provided a good stand is obtained. This is not difficult if the ground is well prepared and properly handled at seeding time. After the alfalfa has become established the expense of maintaining the crop is slight, and the chief expense in connection with alfalfa production consists in irrigating in certain sections and in harvesting and marketing the crop.

In some sections where alfalfa grows well it is not a competing crop with sugar beets, because of the remoteness of these areas from the market, but in cases where the alfalfa is used locally to advantage or where the markets are accessible it competes strongly with the sugar beet and may exclude the latter to such an extent that beet production is so reduced that the operation of a sugar mill is not possible. A sugar mill should have a sufficient quantity of beets to insure a run of at least 100 days each year, whereas the average run for 1917 was only 74 days. (Table IV, p. 34.) Sugar beets may be grown in rotation with alfalfa to good advantage under certain conditions, and our studies have shown the advantage of these conditions in several instances. This is especially true if the farmer looks upon the alfalfa crop as a soil-improving crop as well as a crop from which direct satisfactory returns may be expected. In such

cases alfalfa may be grown two or three years, and at the end of this period the last crop of alfalfa is plowed under for the improvement of the soil, thus putting it in good condition for one or two crops of sugar beets. It is not desirable to grow sugar beets immediately after old alfalfa, because the old alfalfa roots are large and woody and interfere seriously with cultivation. It is better to follow old alfalfa with a noncultivated crop, such as grain, which in turn may be followed by sugar beets.

TABLE IV.—*Beet-sugar production, 1916-17.*

Location and year.	Number of sugar mills.	Days operating.	Acres of beets harvested.	Average yield in tons per acre.	Total tons of beets produced.	Average percentage of extraction.	Average percentage of sugar in the beets.	Average coefficient of purity.	Tons of sugar made.	Average price paid per ton for beets.	Total paid for beets.
California:											
1916.....	11	108	141,097	10.37	1,462,895	16.15	18.35	84.13	236,322	\$6.30	\$9,311,000
1917.....	14	92	161,909	8.16	1,321,716	15.84	18.48	82.91	209,325	7.60	10,125,000
Colorado:											
1916.....	14	102	188,568	10.25	1,933,591	13.04	15.00	85.79	252,147	6.06	12,236,000
1917.....	15	91	161,476	10.84	1,749,875	13.39	15.40	85.16	234,303	7.28	13,526,000
Idaho:											
1916.....	5	86	42,135	7.87	331,478	13.84	16.95	86.39	45,874	6.16	2,199,000
1917.....	7	70	37,745	7.59	286,446	13.40	16.74	84.84	38,376	7.06	2,203,000
Michigan:											
1916.....	15	49	99,619	5.05	502,705	13.79	16.37	85.22	69,341	6.14	3,337,000
1917.....	14	53	82,151	5.62	461,721	13.91	16.28	86.57	64,247	8.04	4,215,000
Ohio:											
1916.....	4	45	24,767	5.56	137,696	13.24	15.89	83.36	18,234	6.83	1,008,000
1917.....	5	70	24,234	8.36	202,624	12.08	16.24	86.25	24,467	7.18	1,580,000
Utah:											
1916.....	11	95	68,211	10.38	708,237	12.75	16.05	84.79	90,277	5.73	4,577,000
1917.....	15	82	80,289	8.68	696,522	12.01	15.61	82.27	83,662	7.04	5,368,000
Other States:											
1916.....	14	66	100,911	8.35	843,071	12.87	15.69	82.67	108,462	6.18	5,471,000
1917.....	21	60	116,993	7.75	906,641	12.22	15.17	81.87	110,827	7.37	7,175,000
All States:											
1916.....	74	80	665,308	8.90	5,919,673	13.86	16.30	84.74	820,657	6.12	38,139,000
1917.....	91	74	664,797	8.46	5,625,545	13.60	16.28	83.89	765,207	7.39	44,192,000

Fruit.—In several sugar-beet areas fruit has been found to be a competing crop. In several instances the sugar beet has been eliminated or shifted to other areas, or reduced in area below the point of a profitable mill run. It is sometimes possible to grow considerable areas of beets in orchards when the trees are small, but as the orchards get older and the trees increase in size the space between the rows must necessarily become smaller and smaller until finally the sugar beet is excluded. When fruit growing has become general in a sugar-beet area, as has been the case in several instances in certain localities, sugar-beet growing and diversified farming in general have been practically eliminated. Occasionally some misfortune overtakes the fruit industry and the area again returns to general farming, including sugar beets. In one locality studied the entire cycle has been passed through, and the fruit growers are now removing their trees and returning to general farm practice, including the growing of sugar beets.

FARM EQUIPMENT.

The equipment on the sugar-beet farm is a matter of vital importance. It covers a wide range of subjects, which may be grouped under four general heads, namely, soil and water, implements, live stock, and labor. If a farm is lacking in any of the essential parts of the equipment and if these parts can not be supplied, successful sugar-beet growing is not possible. The equipment differs to some extent in different localities, especially between the humid and irrigated sections.

SUITABLE SOIL.

As previously noted, a suitable soil, together with a satisfactory subsoil, is one of the first requisites in the production of sugar beets. Soil is not usually classed as a part of the farming equipment, but it is in fact a very essential part. If the soil is very sandy or extremely rocky, it is not probable that it would pay to undertake the growing of sugar beets. Certain conditions of soil may be changed or modified by proper cultural methods, so that an otherwise unfavorable soil condition may be changed to a sufficiently favorable condition to enable the farmer to produce a satisfactory crop of beets; for example, a hard subsoil may sometimes be broken up in such a manner that a sufficiently deep soil for the production of beets is produced. Again, an infertile soil due to lack of humus, to a scarcity of lime, or to improper crop rotation, etc., may be remedied at a small cost and an otherwise unproductive soil rendered productive. As already noted, a soil containing an excess of moisture or one in which the water table is too near the surface may be made productive by proper drainage. It is apparent, therefore, that soil, from the standpoint of equipment, may be a permanent limiting factor, which in some cases can not be overcome sufficiently to enable the farmer to produce a satisfactory crop of beets, while, on the other hand, this part of the farmer's equipment may in many cases be modified by proper treatment and the barrier to sugar-beet production removed. This part of the farm equipment, however, like work stock, implements, etc., is just as essential for the production of other crops as for the production of sugar beets.

IMPLEMENTS.

Many of the implements used in sugar-beet growing are the same as those used in the production of other crops, though some special implements are necessary in order to grow sugar beets successfully; this is especially true of the drill shown in Plate I, figure 1, and the cultivator, Plate IV, figure 1.

Drills and cultivators.—Sugar beets are grown in rows about 20 inches apart, and there is a special drill for the planting of sugar-

beet seed. There are a number of sugar-beet drills on the market which seem to be fairly satisfactory. In some localities the farmers own their beet drills, and in others they are owned by the sugar companies and rented to the farmers at a small charge per acre. Most of the drills made for planting sugar-beet seed are so constructed that they will plant four rows at a time, as shown in Plate I, figure 1. Likewise, the cultivator is especially adapted to sugar-beet work, and will cultivate four rows corresponding to the drill. This is very important, as will be noted by those who have had experience in using a cultivator in such narrow rows. In planting four rows at a time many deviations from a straight line will occur in each of the four rows, which can, therefore, be followed more readily with a 4-row cultivator with less damage to the plants. The beet cultivators are usually equipped with various implements for stirring the soil, depending upon the soil conditions and the size of the beets.

Plows.—The ordinary walking or riding plow can be used in turning the soil in the preparation of the seed bed. The two-way plow is well adapted to the sugar-beet crop, for the reason that it produces no dead furrows. This is especially important in the irrigated areas. In some localities the disk plow is frequently used, although the ordinary moldboard plow is in most common use. The advantage of the disk plow for deep plowing is that it enables one to stir the soil to a good depth if the plow is properly constructed and adjusted, without bringing too much raw soil to the surface. The plows in use vary from the walking moldboard plow through various types of sulky plows to the disk plow, with its numerous variations. In some types of soil it is especially desirable to give an occasional deep plowing.

The best results are obtained by fall plowing, as has been shown by our survey as well as by personal experience. Fair results may be obtained by spring plowing, provided the soil has been previously in good tilth.

Harrows.—In preparing a seed bed for any crop the disk harrow is a valuable implement. It is frequently used to advantage before the ground is plowed. When so used it puts the surface of the ground in such condition that holes or spaces are nowhere left when the ground is turned with the plow. The disk harrow is used sometimes in breaking up lumps or clods after the plowing has been done; however, if the ground has been plowed when in good condition and has been properly treated after plowing, there will be no large lumps or clods, and hence no necessity for the use of the disk harrow to break them up. In case weeds start before the time for planting the sugar-beet seed, the disk harrow is sometimes useful in destroying the weeds. The proper preparation after the ground

is plowed consists in harrowing, preferably with a spike-tooth harrow or other form of this implement, which simply stirs the surface of the ground and makes a moderately fine mulch. It is a more or less common practice to harrow at the end of each half day or, at the latest, at the end of each day, the ground just plowed. This is a practice to be especially recommended in cases of spring plowing, since it has a tendency to hold the moisture in the soil, thereby leaving it in good condition to form a satisfactory seed bed. In case of fall or winter plowing it is better to leave the ground rough, in order that it may catch or hold the winter snows and rains.

The scraper and float.—In the irrigated sections leveling is sometimes necessary in order to put the ground in condition to be irrigated. As pointed out on page 21, ground which is not level or nearly so can not be satisfactorily irrigated. This is especially true with a crop like sugar beets, which must be irrigated by the furrow method. If the ground is leveled before the plowing is done, the Fresno scraper is commonly used. If the leveling is left until after the ground is plowed, an implement called a float is frequently used; this consists of two planks placed on edge and so framed together, about 6 or 8 feet apart, that they can be dragged sideways over the field, as shown in Plate V, figure 2. This has the advantage of not only leveling the ground, but it tends to break up the small clods and puts the ground in good condition for further preparation of the seed bed. Frequently the Fresno scraper is used before plowing if the surface is very uneven, and the float is used after plowing in the same field. The two operations are quite distinct; the former is usually called scraping and the latter leveling. The scraping is necessary only when inequalities in the surface of the field are very marked. The time and labor spent in leveling will be repaid in the production of sugar beets, both from the standpoint of yield and from that of labor saved in irrigating.

The roller.—Another implement of considerable importance in sugar-beet growing is the roller. There are two types of this implement, as shown in Plate II, figures 1 and 2, namely, the smooth roller and the so-called corrugated roller. The latter is desirable in those localities where there are high winds, since the corrugations tend to prevent the soil from shifting under the influence of the wind. The chief advantage of the roller is its surface-packing effect. If the root bed is inclined to be loose the subsurface packer should be used immediately after plowing. As previously noted, the seed bed for sugar beets should be decidedly firm, for two reasons at least. The firmness of the seed bed tends to hold the moisture, and at the same time it prevents the sinking of the drill wheels, in which case the seed is frequently planted too deep. The seed bed that is unevenly

firm or in which there are soft spots or areas is always unsatisfactory, as it results in an uneven start of the beet plants, which interferes with the handling of the crop.

Harvesting tools.—At harvest time the beet lifter, a special implement not required in harvesting other crops, is necessary. (Pl. VII, fig. 1.) There are two forms of this implement, namely, the double-pointed lifter and the side lifter. In the former, one point passes along each side of the beet root at a depth of several inches below the surface and is so constructed that the beets are loosened and slightly lifted. The side lifter passes along one side of the beet row and loosens the beet, usually without lifting it; in either case the roots, after they have been loosened, can readily be pulled and thrown into piles. Care should be taken in using these lifters to see that the beet roots are not broken. Considerable loss frequently results to the grower from the breaking of the roots so that the lower part of the beet is left in the ground.

In topping beets by hand, heavy knives closely resembling a large butcher knife are used; in some localities sickles are used for this purpose. This work, now done by hand, as shown in Plate VII, figure 2, may be done by machinery. (See also Pl. VIII.) In loading the beets on the wagons specially constructed forks should be used. The special construction consists of a knob of metal on the end of each tine, so that the beets are not punctured when they are forked on to the wagon. Special beet racks, as shown in Plate VI, figure 2, are commonly used in hauling the beets to the factory or dump. These special racks are necessary in facilitating the unloading of the beets at the dumps, where the beets are emptied from the wagons on to the cars. If the beets are forked from the wagon the ordinary wagon box may be used, but generally the beets are dumped, in which case racks with hinged sides are necessary. Furthermore, the special rack holds more roots than the ordinary wagon bed, thereby reducing the cost of delivering the crop.

Sugar-beet harvester.—Heretofore the most laborious operation connected with beet culture has been the harvesting. This operation consists of three parts, lifting, pulling, and topping, as described above. The pulling and topping have been done entirely by hand at a cost of \$7 to \$9 per acre. Many attempts have been made in this country and in Europe to construct a mechanical harvester. Recently, several types of this implement have been improved, and it is expected that they will be available to harvest at least a part of the 1918 acreage. One type of harvester, as shown in Plate VIII, figure 1, is a motor-driven device which lifts the beet entirely out of the ground and tops and piles the roots. Another type of harvester, as shown in Plate VIII, figure 2, is a horse-drawn implement which

tops the beet and then lifts the root. Each implement is operated by one man; hence the saving in labor and in labor cost are considerations that appeal to the beet grower at this time when the labor shortage is acute.

LIVE STOCK.

The live stock on the sugar-beet farm should consist of work stock and other animals. One of the most important parts of the necessary equipment on a beet farm is the work stock, which should be sufficient in number, size, and quality to handle the work readily. For the heavy work, such as deep plowing, lifting, and hauling the beets, heavy work animals, such as those shown in Plates II, V, and VI, are desirable. The size and quality of the work stock, therefore, is an essential part of the equipment. The horses should be capable of being trained so that they will follow rows when cultivating. Large animals, if properly trained and handled, will do this work without injury to the beets and may be used unless small animals are available for this purpose. Apparently the tractor is taking the place of work animals in some localities for many of the operations on sugar-beet farms. A farm tractor should be of simple and durable construction, moderate in price, easily and cheaply operated, and capable of making fair speed when required.

Animals other than work stock are essential on the sugar-beet farm in order to utilize to the best advantage the beet tops and pulp as well as the other feeds grown in rotation with the beets, and also to furnish the necessary farmyard manure required to keep up and improve the fertility of the soil. The particular kind of stock, whether dairy cows, beef cattle, sheep, etc., will depend upon the locality, especially with reference to the markets, upon the kind of labor obtainable for handling the stock, and upon the other farm crops produced.

LABOR.

The question of labor on a beet farm is of vital importance, and unless labor is available at the proper time it will constitute a limiting factor in sugar-beet production. Other things being equal, a beet grower with sufficient dependable labor of good quality at his command will handle the crop to the best advantage. For those growers who have not a sufficient amount of labor available for the production of sugar beets in addition to the other farm work, the sugar companies will usually undertake to obtain laborers. These laborers usually are transient, coming into an area at the beginning of the growing season, caring for a given acreage of beets during that season, and returning to their homes after the beets are harvested. In some instances they go out year after year to work in the same locality and for the same farmers. Frequently they rent land

after a few years of experience and remain in the community throughout the year; such workers sometimes purchase land, thereby becoming landowners and employers of labor. The labor imported into an area for work in connection with sugar beets is handled under contract at a fixed price per acre. Before he leaves his home the laborer demands a contract stipulating the acreage that he will be allowed to handle and the price per acre that he will receive for the labor. Labor problems are more fully treated on pages 41 to 43.

BEET BY-PRODUCTS AND LIVE STOCK.

Live stock on a sugar-beet farm constitutes an important factor in the success of beet growing from two standpoints: (1) The utilization of beet tops and pulp and (2) the production of stable or barnyard manure.

Kind of live stock to feed.—Sugar-beet tops and pulp are good feed for all kinds of live stock, including chickens, hogs, sheep, cattle, and, to some extent, horses. Generally the tops and pulp are fed to sheep and cattle. There are several methods by which the beet tops may be utilized for feed. They may be pastured off, a process which consists in turning the live stock into the beet field after the beets have been harvested and the roots removed, as shown in Plate IX, figure 1. The tops are left scattered over the ground, and this method of feeding results in the ground being more or less trampled. Sheep especially are inclined to travel more generally in paths, thereby trampling the ground unevenly. In no case should the pasturing of the tops be permitted when the ground is wet, since the ground itself would be seriously injured by trampling in that condition and many of the tops would be wasted by being trampled into the ground. While live stock thrives on beet tops and pulp, other feed must be used in finishing the animals for the market. Beet tops, especially the crowns, contain considerable mineral matter which is beneficial to live stock, but it should not be fed in too large quantities. Aside from pasturing the tops they are sometimes allowed to cure partly and are then gathered into piles, hauled to the feed yard, and fed in racks, one form of which is shown in Plate IX, figure 2. This is a much more economical method of utilizing the tops, but it involves the additional expense of gathering and hauling. The tops may also be used as ensilage. When chopped with straw, cornstalks, or other roughage excellent silage is produced. Both the tops and the pulp are excellent for dairy cows, since they act as a tonic upon the animals as well as a food and increase the flow of milk. Pulp is used either fresh or dried. It is dried artificially, either by itself or in combination with molasses. When dried by itself it contains the same substances as when fresh; when dried with molasses it, of course, contains the added sugar and mineral matter. The object



FIG. 1.—LIFTING THE BEETS, THE FIRST OPERATION IN HARVESTING THE CROP BY HAND.



FIG. 2.—TOPPING AND PILING A CROP OF SUGAR BEETS BY HAND.

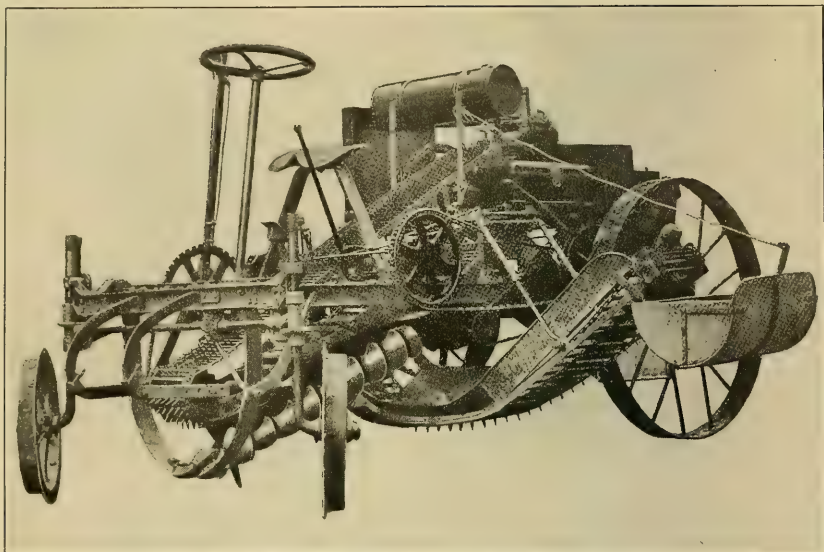


FIG. 1.—A MOTOR-DRIVEN BEET-HARVESTING MACHINE.

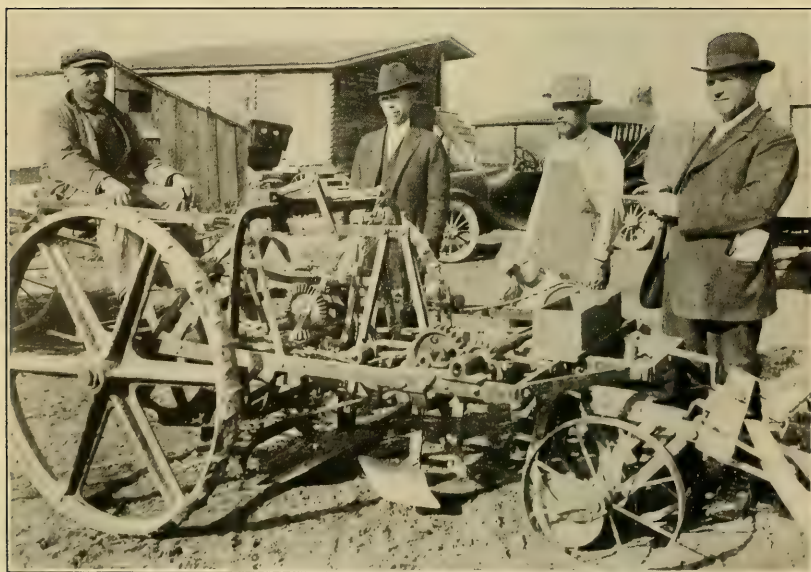


FIG. 2.—ONE TYPE OF HORSE-DRIVEN BEET HARVESTER.



FIG. 1.—PASTURING BEET TOPS AFTER THE ROOTS HAVE BEEN HAULED AWAY.



FIG. 2.—FEEDING BEET TOPS IN RACKS, A METHOD LESS WASTEFUL THAN PASTURING.

in drying the pulp is to make it easier to handle. About 80 per cent of the weight is lost in drying and when dried it can be shipped long distances. It should be soaked for several hours before it is fed to stock.

Number of live stock to keep.—It is apparent that there should be a suitable ratio between the number of live stock and the available tops, pulp, and other feed on the farm. As stated above, animals can not be finished for the market on the beet by-products, and unless other feed is available it will not be advisable to purchase animals for feeding purposes with a view to turning them on the market later. If the farmer is provided with dairy cows, it is advisable to furnish them with one or two feeds of tops or pulp each day. The tops, when cured or pitted, will keep for several months; the pulp when left in a large pile will not spoil for feeding purposes, except in a thin layer on the surface. If the tops or the pulp are fed heavily to dairy cows, a distinct increase in the flow of milk marks the top and pulp-feeding period, and there will generally be a distinct falling off in the flow of milk when this feed is discontinued. Since the supply of tops and pulp is limited, it is better to continue the feeding over a longer period, giving a smaller amount to each of the animals daily. The tops and pulp should always be fed in combination with other feeds in order to make a balanced ration.

LABOR PROBLEMS.

One of the most serious problems on many of the beet farms is that of labor. The difficulties in connection with the labor question as related to sugar-beet culture are due to the fact that a part of the work must be done by hand and is tedious and, furthermore, the labor in connection with this crop is not continuous. For example, there is a period in the spring when considerable labor is required for the blocking and thinning of the beets, as shown in Plate III, figure 1. The work during midsummer is light, consisting of a little hoeing. In the fall there is another increase in the labor requirement, due to the harvest, followed by the winter months, when little or no field work in connection with this crop is done. The need for labor at harvest time is apparent, as the beets must be harvested promptly when they are mature. The reasons for pushing the beet harvest are several: Fall rains may set in and cause the roots to deteriorate in quality, the roots may be frozen in the ground if harvest is delayed, the mill must have sufficient roots to operate continuously, and the farmer must get the beet crop out of the way in order to do his other fall work. The question of securing and holding the necessary labor for the handling of this crop has been one of the serious problems in sugar-beet growing in this country. Beet

labor may be classified under three heads—the family labor, the community labor, and the hired labor, the latter being divided into several classes, such as regular, transient, and contract labor.

Family labor.—By this term is meant the labor furnished by the family which has contracted with the sugar company to grow the beets. It may be the family of the landowner or the family of the tenant. Usually the most successful operations in sugar-beet growing are in those localities where the labor is handled by the family of the grower. In these localities the beet acreage per farm is usually small and the beet labor is not burdensome. This class of labor is usually more vitally interested in the success of the crop than other kinds of labor and therefore greater pains are taken to produce and maintain good stands.

Community labor.—By community labor is meant the exchange of labor between the beet-growing families in a given community. Usually not all the beets in a given community are ready to be thinned or harvested at the same time, and since both of these operations must be done as promptly as possible when the beets are ready, it has been found advantageous for families in the same community to use the exchange-labor method in handling this crop. This exchange system is not confined to the beet crop, but is a common practice in many localities in carrying on all kinds of farm work which needs to be done quickly, such as haying and grain harvesting.

General labor.—By general labor is meant that labor which is employed by the day, month, or year for the general farm work. Transient labor is that part of this labor that comes and goes without any certainty as to its permanency and with little responsibility as to the results of the work. It is seldom used in handling the sugar-beet crop, as it is not sufficiently dependable. All farming communities are familiar with this kind of labor to a greater or less extent. It is unreliable and unsatisfactory, but sometimes enables a farmer to get through a temporary rush period without serious damage to his crop. On many farms there are monthly or annual laborers who take part in all of the farming operations, including the sugar-beet work. Usually this class of labor is very satisfactory in the beet fields, and those farmers are fortunate if by the aid of their general helpers they are able to care for the beet crop in addition to the other work.

Contract labor.—This is the most common class of labor employed to do the handwork in caring for the sugar-beet crop, and, as the word implies, the work is done under contract. The term contract labor as used in this connection is often misunderstood. It is thought by some who are not familiar with beet-growing conditions that the so-called beet-labor contracts are decidedly to the advantage of the landowner or of the sugar company and that such labor is compelled

to work under contract. Usually the sugar company has no interest in the contract labor except in helping the grower to get his work done at the proper time and in the best possible manner. The landowner or beet grower desires a contract, so that he will be sure of the necessary help in handling his crop at the proper time, but above all the laborers themselves desire a contract which specifies the number of acres that a given individual, family, or other group of workers will be permitted to handle and the price that they will receive per acre for their labor. These contracts are usually made with so-called labor families, although individuals and groups of individuals sometimes enter into the contracts. The labor families are usually in the cities during the winter, employed in mills or factories, and in the summer they go out and work in the beet fields. For their own protection they must have a contract before they can afford to leave their employment to take up a new line of work. Many of these families return from year to year to work for the same beet growers. The contract labor usually covers all of the handwork used in growing the beet crop; namely, the blocking, thinning, hoeing, pulling, and topping. The landowner and tenant do all the teamwork, from the plowing of the land to the hauling of the beets to the sugar mill or loading station. The hand laborers usually work for a specified rate per acre, a part of which amount is furnished them after each operation. Occasionally they receive a specified bonus for each ton above a yield agreed upon. The object of this bonus is to encourage the laborers to maintain the best possible stands and to produce the highest possible yield per acre.

During the present acute labor shortage many localities have organized the school boys and girls, especially for the beet-thinning work.

THE SUCCESSFUL GROWER.

The successful production of sugar beets on any farm depends on a great extent upon the temperament of the farmer and upon his attitude toward the production of this crop. As in other lines of business, the man's ability to conduct his business successfully is largely a matter of individual temperament, judgment, and ability to do the right thing in the right way and at the right time. There are many farmers, as there are many men in other lines of business, who are not adapted to the kind of work upon which they are engaged. It is not to be expected that these men would have any more success in the growing of sugar beets than in other lines of agriculture. Again, there are farmers well adapted by temperament to the particular line of farming which they are following, but who would not be successful in some other line of agriculture; for example, a man might grow grain on a large scale and do it very

successfully. He might not at all be adapted to dairying or to the feeding of live stock. Some people can not handle live stock successfully, even though they have right ideas in regard to the handling of crops; likewise, the grain farmer may not be adapted to the growing of sugar beets. Frequently grain production is extensive rather than intensive, while sugar beets should be handled intensively rather than extensively. At any rate, intensive methods should be employed in growing this crop. Some growers of the extensively grown crops, like grains, forage, etc., sometimes become very successful growers of sugar beets, but generally they prefer the line of agriculture which they have followed and from which they do not wish to depart. The same is true of the live-stock man, although the man who handles live stock, especially dairy cows, is more inclined to take up the growing of such an intensive crop as sugar beets and is more apt to succeed in this line of agriculture than the grain or forage crop man. This does not apply, however, to the live-stock man who grows for the market, and especially the man who produces or handles large herds of cattle. The point to be made in regard to the grower is that he must have the natural qualifications for intensive agriculture and must be fitted by training and experience for the growing and handling of crops requiring intensive cultivation.

DISEASES.

Diseases are among the most apparent limiting factors in sugar-beet production. A crop of beets that might otherwise be very profitable is frequently turned to a loss by some disease. The sugar beet, like all other plants, is subject to disease from the time it begins its growth until it is harvested; and even after the plants are harvested, if stored under certain conditions, the beets may decay to a greater or less extent, impairing or destroying their value for sugar-making purposes. Some of the diseases are well known and easily controlled; others, while known, are handled with difficulty; and still others are obscure as to their causes. The losses produced by diseases may be brought about by a destruction of the plant itself or by some injury which reduces the size or quality of the beet root.

Damping off.—Among the diseases which attack the beet during the early stages of its growth is the so-called damping-off. There are several forms of this disease, due, apparently, to different organisms. Frequently the young beet plants turn black just at the surface of the ground, fall over, and die. Sometimes the entire root turns black and softens, and sometimes the blackening is confined to the outer layer or epidermis. In the latter case the beets frequently recover. This disease is caused either by a fungus or a bacterium which is in the soil or on the seed when planted. If the disease is

widespread, so that the stand is seriously injured, the field should be disked and replanted. Damping-off is more common in the early spring, when the ground is damp and not thoroughly warm, but the disease will not occur unless one of the damping-off organisms is present.

Nematodes.—The sugar-beet nematode is a minute wormlike organism, sometimes called an eelworm, which attaches itself to the root and when present in sufficiently large numbers retards the growth of the beet. There are several species of the nematode which attack the sugar beet, but only one is considered especially serious; hence, this species is known as the sugar-beet nematode (*Heterodera schachtii*). This pest has been known for many years in Europe and has existed in isolated localities in this country for more than a decade. It is spreading, both by its own activity in certain stages of its existence and by being carried from the present infested areas by various agencies. The pest lives in the soil from year to year and travels slowly, so that the infested area is gradually increased, until frequently an entire field or even a group of fields may become useless from the standpoint of beet production. Unfortunately, this pest will attack many plants besides the sugar beet. This makes it extremely difficult to control by crop rotation, which is one of the best methods known for the control of many of our plant pests. However, there are a number of plants that the nematode attacks to a very slight extent or not at all. Again, the nematode passes through several stages of development; one of these is known as the brown-cyst stage. In this stage the nematode is very resistant to unfavorable conditions and will remain alive in the soil for a number of years; the exact length of time is not known. The Office of Sugar-Plant Investigations is making every effort to determine the crops that are resistant to the nematode under the local soil and climatic conditions where the nematode exists and also to determine the proper length of the rotation with these resistant crops, so that the nematode will be eradicated or at least reduced to such a small number that sugar beets may be grown with profit. Various soil treatments also are being tested on nematode-infested areas. Some of these tests are very promising but will need to be repeated before anything definite can be said regarding their beneficial effects. Careful surveys have been made in some of the infested areas, and all fields or spots in fields containing nematodes have been listed and marked, either for study or for the purpose of growing crops other than sugar beets on them. A similar campaign is planned in the other infested areas where the sugar-beet nematode has gained a foothold, while a careful watch is being kept over all sugar-beet areas in order to detect and combat the pest on its first appearance.

Curly-top.—This disease of the sugar beet is confined to the western part of the United States. So far as is known, it has not been

seen in the eastern portion of the sugar-beet area or in any of the beet fields of foreign countries. It has appeared in practically all States west of Minnesota and Iowa where sugar beets are grown commercially, although it has not been seen in all of the sugar-beet areas of the West. It is not due to unfavorable climatic or soil conditions, nor is it due to the kind or quality of seed used. It is connected in some way with a so-called leafhopper, which appears to be only a carrier and not the real cause of the disease. A further study of curly-top is being undertaken by the Office of Sugar-Plant Investigations in cooperation with the Bureau of Entomology, in the hope of being able to determine the exact cause of the disease, and especially for the purpose of finding some practical means of control. Curly-top does not usually occur to any serious extent two years in succession in the same field, although there are some exceptions to this rule. Frequently it will occur over a given area, destroying or stunting to a worthless size practically all of the beets for a season and then almost entirely disappear, so that the next year beets of good tonnage and quality may be grown on the same fields. It is possible that there are other carriers besides the leafhopper and that certain soil and climatic conditions favor the development of this disease. The real cause, however, is undoubtedly organic in nature; it is probably either an organism or an organic compound; but until this cause is known little progress can be made in finding a reliable method of control. Curly-top has played an important part in closing at least two beet-sugar mills and has caused losses of hundreds of thousands of dollars in other localities.

Root-rot.—There are several destructive diseases of the sugar beet known as root-rot. One of these is due to a fungus called *Phoma* and another is due to a fungus known as *Rhizoctonia*. Other root-rots less extensive or little known are due to other fungi or to bacteria. The *Phoma* rot seems to be more prevalent and more destructive than the *Rhizoctonia*. These fungi attack the beets in the field, usually in midsummer. Sometimes they destroy the plants before they are harvested, causing a serious loss to the grower. In other cases they make only a slight attack on the beet in the field, but develop more or less rapidly when the beet has been placed in storage, either for sugar-making purposes or for seed production. The *Phoma* fungus causes more loss to stored roots than any other agency, especially if the temperature favors the development of the fungus. These diseases are found in all parts of the sugar-beet area in this country and in Europe. The most successful means of combating the root-rot of beets in the field is crop rotation, and if it does not get started in the field there is little danger of its developing in storage.

Leaf-spot.—There are two fungi that produce spots on the leaves of beets which are more or less general throughout the United States

and Europe. One of these is known as *Cercospora* and the other as *Phoma*; the latter is the same fungus that produces the root-rot. When the spores of either of these fungi fall upon the beet leaves and the conditions are favorable the fungus growth attacks the tissue of the leaf, producing distinct and characteristic spots. The *Cercospora* fungus does not generally attack any part of the beet plant except the leaf blade and the petiole, while the *Phoma* may attack leaf and root. If these fungi are present in large numbers they may do considerable damage to the beet crop. If the attacks are severe early in the season, the growth of the beets is retarded and consequently the yield is reduced. If the attacks do not occur until late in the season, after the beets have practically reached their normal growth, the diseases will reduce the sugar without appreciably affecting the tonnage. If these fungi attack the beets in midsummer, both the yield and the quality will be generally reduced. These diseases may best be controlled by deep fall plowing and by crop rotation. Crop rotation is especially recommended where it can be practiced, but in cases where it is necessary to follow beets with beets after these diseases have appeared, the ground should be plowed in the fall to a good depth, not less than 12 to 14 inches. In fact, all plant-pathological problems, from a practical standpoint, are closely connected with the cultural phases of crop production. Production can not be successfully studied without a knowledge of the diseases affecting that particular crop, nor can the disease of a crop be intelligently considered with reference to control measures except in conjunction with the cultural practices and with a knowledge of the conditions under which that crop is grown.

INSECTS.

The principal insects affecting sugar beets have been treated in various publications of the Bureau of Entomology. A list of these publications is given at the end of this bulletin. Among the important forms which affect the leaves are the webworms and the beet army worm. In some localities blister beetles, flea beetles, and local pests do considerable damage, mainly by destroying the foliage. They also have a retarding effect on the growth of the beet, but the principal injury is due to the destruction of the foliage and the consequent expenditure of energy and food required by the plant to produce a new set of leaves. Usually these insects start in small areas on one side or a corner of a field and spread rapidly. Of some species there are several generations in a season, and if weather conditions favor their development much damage is frequently done. In the case of insects working early in the season the tonnage of the beets may be greatly reduced, and if the insects continue until late

in the season the sugar content also will be lowered considerably. Sugar-beet insects as a general rule are more or less local and are seldom very destructive for more than one or two years in succession.

All biting or chewing forms of insects are susceptible to poisons and may be controlled by the use of arsenate of lead, Paris green, or other arsenicals.

The leafhopper previously mentioned as a carrier of curly-top is frequently very destructive indirectly. It punctures the leaves or leaf blades of the beets with its slender beak and injects into the plant some substance or organism which exerts a decidedly unfavorable effect upon its growth.

Among insects working in or near the roots are cutworms, wireworms, and white grubs, all of which are very destructive. White grubs are abundant in sod land; therefore such lands should not be selected for growing sugar beets. Wireworms and cutworms as a rule are more destructive early in the season while the beets are small. They frequently destroy the stand to such an extent that replanting is necessary. Cutworms come from the surface of the ground and cut off the plants during the night. They may be destroyed by the use of poisoned baits, according to directions which will be furnished by the Bureau of Entomology. Wireworms usually follow the row of young beets when they have begun their work of destruction, and since they usually remain in a row a second planting should be made in the same direction, so that the rows are parallel and several inches from the original planting, i. e., without harrowing or disking. By pursuing this method the second planting will often become so large that little wireworm damage will be done. Other remedies, however, are necessary.¹

The false chinch bug is a serious enemy to seed beets, frequently appearing in immense numbers and working on the growing tender seed stalks and leaves. When present in large numbers it frequently absorbs by suction so much of the vital juices of the plant that either the seed stalks are destroyed or the seed fails to mature. This insect may be controlled by the use of contact sprays, among which nicotine sulphate, 40 per cent, is most valuable. Experiments in cooperation with the Bureau of Entomology are now in progress to determine whether or not spraying seed-beet fields is a practical method of controlling this pest.²

BY-PRODUCTS.

The principal by-products connected with sugar-beet growing and beet-sugar production are the beet tops, pulp, and lime. The first

¹ See Bulletin 123, Bureau of Entomology, U. S. Dept. Agr., "A preliminary report on the sugar-beet wireworm," 68 p., 23 pls., 9 figs. 1914.

² See Farmers' Bulletin 762, "The false chinch bug and measures for controlling it," 4 p., 2 fig. 1916.

two of these have already been considered under live stock. The lime is an important by-product of the mill used in purifying the juice in the process of separating the sugar from the nonsugars in solution. For this purpose limerock is obtained and burned. The limerock should be as pure as it is possible to find it and should be thoroughly and evenly burned. The beet juice is treated with this burned limerock, and a large part of the mineral matter taken up by the beet plants in the process of growth combines with the lime and is removed by filtering. The lime is then washed out or otherwise removed from the mill and is known as waste lime or lime sludge. Large quantities of this material accumulate at the various mills and may be used as a soil improver and as a fertilizer. It is beneficial not only because of the lime, which tends to improve the physical condition of the soil, but because of the mineral matter that the lime has removed from the beet juice. The use of this material as a fertilizer has not come into general use in this country. In some of the beet-sugar countries in Europe this by-product is all used in making commercial fertilizers. It is used in part as a filler in the manufacture of fertilizer and in part as a soil improver just as it comes from the sugar mill. It therefore has in this country two possibilities: First, it may be used just as it comes from the mill, and, second, it may be used in the manufacture of commercial fertilizers. When first removed from the mill it is wet and can be handled with difficulty, but it soon dries sufficiently to be handled readily, is friable and easily incorporated with the soil, and should all be used in improving farm lands. In some localities where the value of this material has been realized it is washed out and carried in ditches or flumes to the fields, where it is spread by the irrigating water. In this way it may be handled quickly at a minimum cost, and if care is taken it may be evenly spread. As soon as the ground on which the lime has been spread is sufficiently dry it should be plowed and the lime thoroughly mixed with the soil. For sugar-beet culture there is very little danger of getting too much lime in the soil. Beets not only thrive well on limed soil, but the lime seems to have a beneficial effect under some conditions in retarding the development of certain plant diseases.

ROADS.

One of the most important factors in developing a beet-sugar industry is that of roads. Certain localities otherwise adapted to sugar-beet growing have been found in which this crop can not be recommended or encouraged because of the condition of the roads. Fortunately, the interest in roads during the past few years has greatly reduced the number of such localities. Road building and sugar-beet culture have been mutually helpful. It is only by having

good roads that crops which must be hauled to market in numerous heavy loads can be handled successfully; likewise the demand that these crops have made for good roads has stimulated their building and improvement, as shown in Plate VI, figure 2. There are three points to be considered in connection with roads as related to sugar-beet culture: (1) The length of the haul, (2) the topography of the country, and (3) the nature of the roadbed. In general it has been found that 4 or 5 miles is the maximum distance that sugar beets can be hauled profitably. It is apparent that the distance depends to a great extent upon the topography and the nature of the roadbed. If the country is hilly, and especially if the hills are steep, it frequently is unprofitable to haul sugar beets. Unless at least 3 tons of beets can be hauled per load the conditions must be very favorable to make the handling of this crop profitable. In the survey by the Office of Sugar-Plant Investigations, cooperating with the Office of Farm Management, it has been found that, other things being equal, the cost of delivering beet roots increases directly with the distance. In this survey the topography and the care of the roadbed were practically the same for all cases compared. It is apparent that it would be more expensive to haul a short distance over a poor or hilly road than several times that distance over a level stone road, as shown in Plate VI, figure 2. In speaking of the hauling distance, reference is made not to the distance from the factory but to the loading station or point of delivery. In this respect the grower near the sugar mill has no advantage over the grower many miles away, provided the latter is near a beet dump.

The railroad haul is another point to be considered. As a rule, beets can not be transported more than 100 miles with profit, at least under normal conditions. There are, of course, circumstances under which longer hauls are permissible and profitable. Frequently in trying out a new sugar-beet section it is necessary to haul the roots several hundred miles, but in such cases it is not expected that any considerable profit will be obtained from these beets, and, in fact, they sometimes are transported long distances at a loss in order to determine whether beets of sufficient yield and quality to make beet-growing profitable can be grown in a given locality. The length of the railroad haul depends to some extent upon the local conditions, the returns that may be obtained, and whether the haul is over a single road or over two or more lines.

CONTRACTS.

All sugar beets grown commercially for sugar-making purposes are grown under contract. These contracts are issued by the sugar company and are signed by some official or agent of the company and also by the beet grower. The principal points covered in the contracts

include the acreage to be planted, the price to be paid for the beets, the methods of handling the crop, the time of harvest, and the regulation of delivery. Contracts are necessary because a definite acreage of sugar beets is required in order to make a successful mill run. Each mill should have enough raw material for at least a 100-day run, although the average operating period for 1917 was only 74 days, as shown by Table IV. It would be a source of loss to the sugar company to undertake to operate a mill with beets enough for only 50 days, or at half capacity. Knowing the average yield of beets per acre in a given locality, it is comparatively simple to determine approximately the number of acres that will be required to produce a satisfactory run under normal conditions. Furthermore, it is important that the sugar company shall have a written agreement or contract setting forth the time of delivery of the beets. Beet roots must be delivered in sufficient quantity to supply the mill from day to day. It is very expensive to close a mill and let it remain idle even for a few hours during the sugar-making period; hence, there must be some understanding with regard to the delivery of the beets. On the other hand, the beets must not be delivered too rapidly, since they might deteriorate in quality if stored too long, especially in certain localities or under certain climatic conditions where the spoiling of the beets before they could be put through the mill might be a matter of considerable magnitude.

The growers require a contract because they must be insured a market for the beets at a fixed price. This is one of the few crops grown on a commercial scale in which the market price is known even before the seed is planted and for which there is no market of any importance except for sugar-making purposes.

There are three general forms of contract so far as the price to be paid for beet roots is concerned, namely, the flat rate, the sliding scale, and the profit-sharing plan. This feature of the contract relating to the price of beets differs with different companies and in different localities.

Flat rate.—The flat-rate contract fixes a definite price which the farmers are to receive for the beets regardless of the quality of the roots. It is usually stipulated in the contract that the roots must possess a specified sugar content and purity in order to be accepted, but in all of the beet-growing areas there is no record that any sound beets have been rejected because of poor quality. The advantage in this clause in the contract lies in the fact that the fields that are not testing as high in sugar and purity as is required by the contract can be held until a later date before harvesting. Usually the sugar content of the roots increases rapidly in the fall, so that a delay of a few days at or near harvesting time frequently means a decided increase in the sugar content and an improvement in the purity of the roots. The flat rate is the price per ton for the clean

and properly topped roots. It differs in different localities and recently has been increased, owing to the high price of sugar.

Sliding scale.—The second form of contract so far as the price of the beet roots is concerned is the so-called sliding scale. The other features in the contract, aside from the price to be paid for the beets, are usually the same as in the flat-rate contract. The sliding scale of beet prices is based either upon the percentage of sugar in the beet or upon the market price of sugar at a given time and place, or it is based upon a combination of the sugar in the beet and the price of sugar. In those contracts in which the scale of prices for beets depends upon the sugar content of the beet root there is a minimum price per ton for a beet of a given quality and an increased price per ton for each per cent or fraction of a per cent of sugar in the beet above the minimum. The minimum price and the minimum quality of the root agreed upon differ in different localities, but are definitely stated in the contract. The rate of increase also varies in different localities; for example, one sugar company may agree to pay a minimum price of \$4.50 per ton for beets testing 12 per cent sugar, while another company may agree to pay a minimum price of \$5 per ton for a minimum of 14 per cent sugar content. They may also agree to increase the price 25 cents or $33\frac{1}{3}$ cents per ton for each per cent of sugar above the minimum.

The price scale for beets, based upon the market price of sugar, was in use in several localities for the first time in 1917. In these contracts the price of sugar at a given time and for a definite, stated period is taken as the basis. If the price of sugar at the place and for the time specified is \$6 per hundred, for example, the price paid for the beets will be \$6 per ton or \$7 per ton, as may be agreed upon and specified in the contract. Usually a minimum price to be paid for the roots is stated in the contract. This would seem to be an equitable arrangement, since the greatest profit to the grower and to the sugar company would result when the price of sugar is high, and both would share the smaller profit or the loss when the price of sugar is low.

Profit sharing.—In the profit-sharing contract the grower is guaranteed a fixed minimum price for beets, the sugar companies to accept a minimum price for sugar, which presumably will give the grower and the sugar company approximately the same profit per ton of beets. It is further agreed that all profits in excess of the amounts above mentioned shall be divided equally between the grower and the sugar company. In areas where this contract is offered the grower, a flat-rate contract is available, if desired.

Tare.—One of the important factors in handling beets is that of tare, and it forms an important clause in the contract. Tare consists of two distinct parts, one of which is the dirt which clings to the

beet roots when delivered and the other is the part of the crown that is sometimes left on the beet when the beet is topped. Tare is obtained by taking a sample from a load of beets and weighing it carefully. The dirt is then removed from this sample, usually by means of a stiff brush, and the beets, if not properly topped, are correctly topped and the cleaned topped roots again weighed. The difference between the original weight of the sample and the clean, properly topped beets is the tare. This is usually reduced to a percentage, and the entire load is tared on the basis of the sample tared. Most sugar-beet tare houses are provided with scales that give a direct reading of the percentage of tare for each sample as it is weighed.

AREA COMPETITION.

The competition between adjacent beet areas may or may not be of advantage to the beet-sugar industry, as a whole, and consequently may or may not be beneficial to beet growers residing within those areas. If the acreage in a given area is sufficient to support two mills, for example, the competition in securing acreage for each of these mills may, if properly handled, stimulate the development of the industry in that area. If, on the other hand, a sugar mill is established in a given area having a limited sugar-beet acreage, due regard being had for proper crop rotation, and a second mill is built in the same area the results may be disastrous to both of the mills and may result in retarding or preventing the development of the beet-sugar industry in that locality.

In all lines of business, competition is desirable under certain conditions, but in the beet-sugar industry a certain acreage of beets is necessary in order to enable a sugar mill to operate on a profitable basis. If a competing mill draws upon the beet acreage in a given locality to such an extent that the raw material is not sufficient to provide a satisfactory and profitable run for either of the mills, one or both of them must necessarily suspend operations. This result must lead to disappointment and financial loss on the part of those who have invested in the mills, and it deprives the growers of the benefits of sugar-beet production, inasmuch as the closing of the mills must necessarily leave the growers without a market for their product.

Sugar-beet producing areas may sometimes be extended by bringing in lands not previously under cultivation, by the development or extension of suitable means of irrigation, or by instituting or extending a suitable drainage system which will reclaim lands not now under cultivation. In this manner areas that are now capable of supplying but one mill with raw material may eventually be made to supply two or more mills. In all cases the necessary acreage for the maintenance of a mill should be in sight, without injury to existing mills or to local growers, before any money is expended in the

erection of a mill. If this point is kept in mind, some of the financial losses and disappointments which investors have experienced in the past will be avoided.

SUGAR-BEET SEED.

One of the most important factors influencing beet-sugar production is that of seed. Not only must there be an adequate supply of seed to plant the necessary acreage for each sugar factory, but the seed must be of high grade, that is, it must be capable of germinating so that a good stand will be produced, and it must be capable of producing beets of satisfactory yield and quality. The present varieties of sugar-beet seed are apparently very much mixed, as indicated by commercial fields in all parts of the beet area. Efforts are being made at each of the beet-seed stations of the Office of Sugar-Plant Investigations to produce distinct strains of high quality for selection and planting. In connection with this work we are endeavoring to increase the yield and quality of the seed and to meet the present emergency by increasing the acreage of beet seed.

Imported seed.—Until within the last four years practically all sugar-beet seed planted in the United States was imported from Europe. This imported seed consisted of more than 20 so-called varieties, many of these varieties being simply strains bearing the name of the growers or the locality where the seed was produced. There appears to be but little difference in results between the varieties imported. More seems to depend upon soil and climatic conditions and the cultural methods used in growing the crop than upon the particular variety of seed used. Under present conditions Russia is the only foreign country from which beet seed in quantity may be obtained, and considerable difficulty is experienced in getting sufficient seed from that source.

Home-grown seed.—In recent years efforts have been made to produce American strains of sugar-beet seed and to produce them in commercial quantities in this country. In 1917 about 5,000 acres of beet seed were grown, yielding about 55,000 sacks of seed, while a still larger crop of American-grown seed is in prospect for 1918. This supply of home-grown seed will do little more than care for the increased number of new sugar-beet areas that have developed during the last two years. Even with an increased home production, we must continue to look to foreign countries for a considerable part of our beet-seed supply. The importations, therefore, must continue to amount to more than 100,000 sacks, of 110 pounds each, if our present acreage of beets is maintained. In order to make our beet-sugar industry safe we should produce annually from 16,000 to 20,000 acres of seed to supply our present mills. This acreage of seed must necessarily be increased from year to year in order to care for its expansion if the American beet-sugar industry is to be made safe and permanent.

**OTHER PUBLICATIONS OF THE UNITED STATES DEPARTMENT
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PUBLICATIONS AVAILABLE FOR FREE DISTRIBUTION.

- Sugar and Its Value as Food. (Farmers' Bulletin No. 535.)
Sugar-Beet Growing under Irrigation. (Farmers' Bulletin No. 567.)
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The Present Status of the Sugar-Beet Seed Industry in the United States. (Separate 695 from Yearbook for 1916.)
Statistics of Crops Other Than Grain Crops. (Separate 720 from Yearbook for 1916.)
The Curly-Top of Beets. (Bureau of Plant Industry Bulletin No. 181.)

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Analyses of Sugar Beets, 1905 to 1910, together with Methods of Sugar Determination. (Bureau of Chemistry Bulletin No. 146.) Price, 10 cents.
[The Beet Army Worm.] In Proceedings of the Twelfth Annual Meeting of the Association of Economic Entomologists. (Bureau of Entomology Bulletin No. 26, p. 79.) Price, 10 cents.

- A Brief Account of the Principal Insect Enemies of the Sugar Beet. (Bureau of Entomology Bulletin No. 43.) Price, 5 cents.
- The Sugar-Beet Crown-Borer. *In* Some Miscellaneous Results of the Work of the Bureau of Entomology. (Bureau of Entomology Bulletin No. 54, pp. 34-40.) Price, 10 cents.
- The Beet Army Worm. *In* Report on Miscellaneous Cotton Insects in Texas. (Bureau of Entomology Bulletin No. 57, pp. 35-36.) Price, 5 cents.
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BULLETIN No. 722

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief



Washington, D. C.

PROFESSIONAL PAPER

October 22, 1918

A STUDY OF HEART-ROT IN WESTERN HEMLOCK.

By JAMES R. WEIR, *Forest Pathologist*, and ERNEST E. HUBERT, *Scientific Assistant, Office of Investigations in Forest Pathology*.

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INTRODUCTION.

From the fact that the experience and methods of the European countries have been worked out and are at present practiced under an entirely different set of conditions, forestry in America is confronted with the necessity of formulating its own fundamentals as regards forest organization, working plan, and general silvicultural procedure in the virgin forests of the Northwest. Since a large number of the basic principles of an ideal forest organization depend upon a proper understanding and appreciation of the progress of decay in the forest and the general deterioration of the stand and of individual trees, the problem is largely one of a pathological nature. The need of reliable figures from which an adequate conception of the loss to the forest through the death and disease of individual trees or stands and through various other causes instrumental in reducing the maximum annual increment is self-evident when any attempt is made to establish a rotation or cutting age for any one species. It is necessary also to concentrate the collection of these data upon a single tree species or upon a single type in order to secure

figures which can be applied to the practical operations of forestry. Meinecke,¹ in a recent paper on this subject, has clearly expressed the need of concentrated work upon single tree species, with a special aim to secure accurate data adaptable to practical use. In order to make a beginning in supplying the fundamental knowledge for a solution of some of the more vital problems bearing on the regulation of the forest with regard to the peculiarities and activities of the more economic fungi, a series of detailed studies has been instituted, beginning with the western hemlock (*Tsuga heterophylla*). In the present study, an attempt has been made to secure for two principal types of the typical stand all available data bearing on the relationship of decay to the many factors concerned in its inception, development, and spread, and to determine, if possible, which of the factors concerned in the life history of western hemlock has the greatest influence in the development or retardation of decay.

PRESENT STATUS OF WESTERN HEMLOCK IN THE TRADES.

The regulation of hemlock in the northwestern forests is probably one of the most difficult silvicultural problems with which foresters have to deal. Not only has this species for many years in some parts of the West been considered little more than a "weed" in the forest, to be removed in as expedient and thorough a manner as possible, but a widespread prejudice on the part of the lumber trade has kept the products of western hemlock much in the background.

The common occurrence of heart-rot, the susceptibility to fire and frost, etc., have also led to a much advanced theory of a general decadence of this really valuable species. Western hemlock can not be considered in any sense a decadent tree, as is evidenced by its splendid height and diameter growth in localities where it reaches its best development. There are approximately 90,000,000,000 feet board measure of western hemlock in the United States and Alaska, and most of this is found in Washington and Oregon.² Only recently have the millmen placed hemlock upon the market under its rightful name. In 1908, 90,000,000 feet of western hemlock were reported cut, and this increased to 248,000,000 feet in 1910.² The rapid increase in cut tends to show that the true value of western hemlock is hereafter to be recognized and that the prejudice against its name is gradually disappearing.

Several mill owners with whom the subject of the soundness and durability of hemlock lumber has been discussed state that too frequently the lumber decays rapidly after being sawed. This is not

¹ Meinecke, E. P. Forest pathology in forest regulation. U. S. Dept. Agr. Bul. 275, 62 p. 1916.

² Hanzlik, E. J., and Oakleaf, H. B. Western hemlock; its forest characteristics, properties, and uses. In Timberman, v. 15, no. 12, p. 25. 1914.

due to a poor physical quality of the wood, but usually arises from the fact that great difficulty is experienced in determining the actual extent of the advance decay from the more evident heart-rot when the trees are bucked and scaled in the woods. Some of the logs go to the mills to all appearances sound, but in reality with a part of the log in the incipient stages of decay. Consequently, when the log is sawed into boards they check or completely fall into a dry crumbly decay when exposed to drying conditions for any considerable length of time. Such conditions cause a discrimination against western hemlock by those who have witnessed this deterioration after sawing. A better understanding of the real causes underlying this result and a true conception of the usefulness of hemlock wood will aid greatly in removing such objections as the trades now hold against lumber sawed from this species of tree.

ECHINODONTIUM TINCTORIUM.

THE FUNGUS AND ITS HOSTS.

With few exceptions, as will be shown, *Echinodontium tinctorium* E. and E. (figs. 1 and 2) is the cause of practically all the heart-rot so widely prevalent in hemlock throughout the Northwest. Being the only hydneaceous fungus of its kind and the only member of its genus, something of its history should be given. The fungus was first described as *Fomes tinctorium* by J. B. Ellis from the original specimens collected in Alaska by J. G. Swan. The teeth were broken from these specimens, and Ellis mistook the pits or scars for pores and called it a *Fomes*.¹ The fungus was next collected at Jansville, Idaho, by C. V. Piper, who sent it to Lloyd. Lloyd published it as *Hydnum tinctorium*.² In a letter to the senior writer, Lloyd states that Ellis suggested that the fungus might well be the type of a new genus and should be called *Echinodontium tinctorium*. Lloyd used this name in his article and it was the first time the name was employed. In 1900, Hennings, of the University of Berlin, received some small specimens from Japan. Ignorant of the work of Ellis and Lloyd, he published the fungus as representing a new genus, calling it *Hydnofomes tsugicola*.³ The name *Echinodontium* first published by Lloyd has become so thoroughly established in forestry circles that any attempt to depose priority and use any other names, which in some respects are far more applicable, for instance, *Hydnofomes*, would lead to some confusion in the ranks of practical foresters; hence the name given by Ellis and Lloyd will be used.

¹ Ellis, J. B. New fungi, mostly Uredineæ and Ustilaginæ from various localities, and a new *Fomes* from Alaska. In *Bul. Torrey Bot. Club*, v. 22, no. 8, p. 362. 1895.

² Lloyd, C. G. Mycological notes, no. 1, p. 2-3. 1898.

³ Hennings, Paul. *Fungi japonici*. In *Bot. Jahrb.* [Engler], Bd. 28, Heft 2, p. 268. 1900.

The chief gross character by which the fruiting organ of the fungus may readily be recognized is a hymenium consisting of numerous firm, thick, sharp-pointed teeth of a light-brown color (figs. 1 and 2). The upper surface is almost black in old specimens (figs. 3 and 4), usually of a lighter color when young, and concentrically zoned, each zone representing a year's growth. In a growing condition the outer zone is white or brown, context solid, and of a Mars-orange to orange-rufous color.¹ The minute characters of the fruiting organ are: Spores hyaline, broadly ellipsoid, 4 by 6 μ , teeth covered with

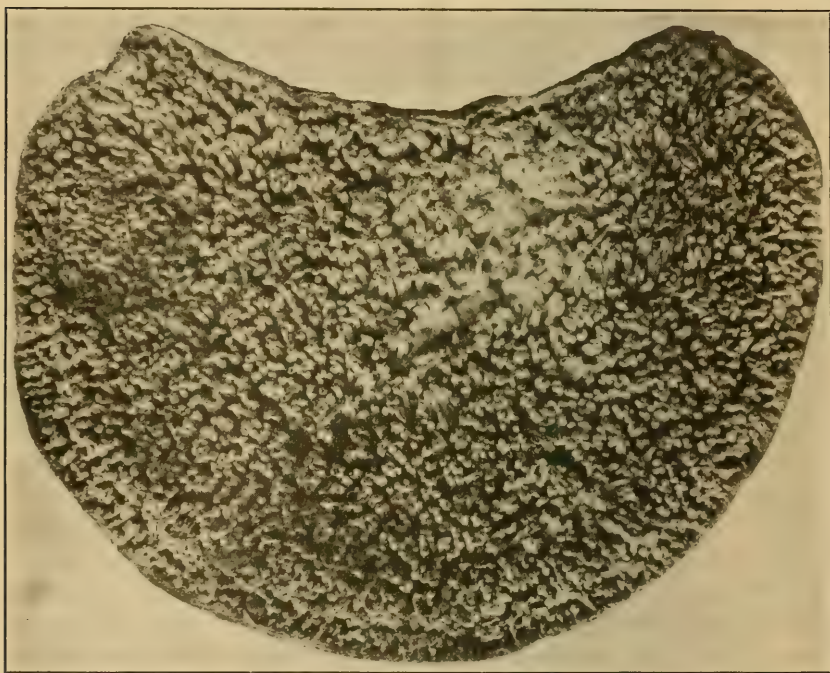


FIG. 1.—Sporophore of *Echinodontium tinctorium* on hemlock. Bottom view, showing fresh hymenium or spore-producing surface.

short colorless setæ or microscopic spines. The hymenium of the young growing fungus is by no means toothed in the beginning but is typically dædaloid, a character often misleading to the uninitiated when the interior has not been examined.

On account of its tinctorial property, the powdered fungus mixed with tar or oil is used by the Indians as a war paint. The fungus is likewise employed by the Indians of Alaska for medicinal purposes and as a dye. For the latter reason it has received the common name of Indian-paint fungus. Since an oily alkaloid has been detected by the analysis of the fungus, there is a possibility of its

¹ Ridgway, Robert. Color Standards and Color Nomenclature, pl. 2. Washington, D. C., 1912.

possessing therapeutic properties of some value. Tannin has been found in considerable quantities in the fungus.

From specimens preserved in the Laboratory of Forest Pathology at Missoula, Mont., the host range of *Echinodontium tinctorium* is as follows: *Tsuga heterophylla*, *T. mertensiana*, *Abies grandis*, *A. concolor*, *A. lasiocarpa*, *A. nobilis*, *A. magnifica*, and *A. amabilis*. The fungus has not been reported on *A. venusta*. Its occurrence on *A. arizonica* is reported by Hedgcock.¹ In the very rarest of cases *E. tinctorium* occurs on *Picea engelmanni* and *Pseudotsuga taxifolia*. The fungus rarely occurs on any but its common hosts and is only of economic importance in the consideration of problems relating to the genera *Abies* and *Tsuga*. The specimens which reached Berlin from Japan grew on *Tsuga diversifolia*.

GEOGRAPHIC DISTRIBUTION.

In view of the fact that many of the more serious wood-destroying fungi are distributed over the world, it is interesting to note that the geographic

range of *Echinodontium tinctorium* is limited. Except the specimens from Japan, it has not been found outside of western North America. To judge by specimens on hand in the Laboratory of the Office of Investigations in Forest Pathology of the Bureau of Plant Industry and as reported by others, the range of this fungus in North America extends from Alaska to northern Mexico and as far eastward as the limits of the range of grand fir and hemlock on the western slopes of the Continental Divide in Canada and Montana.



FIG. 2.—*Echinodontium tinctorium* growing out of a blaze, which was the source of infection. Note the spines on the fungus.

¹ Hedgcock, G. G. Notes on some diseases of trees in our National Forests. In *Phytopathology*, v. 2, no. 2, p.78. 1912.

The fungus is most abundant and of greatest consequence in western Montana, Idaho, Oregon, Washington, and British Columbia.

THE DISEASE CAUSED BY *ECHINODONTIUM TINCTORIUM*.

OUTWARD SIGNS OF THE DISEASE.

To be able to recognize or discriminate between the more dangerous and less harmful diseases should be a part of the everyday knowledge of the forest officer in charge of the marking. The following statements will be of some value in this respect.

The decay-producing fungus proper is the mycelium in the wood, not the "conk" (fig. 5) without. The appearance of a fruiting body



FIG. 3.—Sporophore of *Echinodontium tinctorium*, showing upper surface.

is in most cases an index of the intensive development of the fungus, at least within a certain volume of the tree infected. It means that a good part of the food materials of the heartwood at that point are exhausted. A single average-sized sporophore situated on the first 16 feet of the trunk for all practical purposes may be taken to indicate an unmerchantable condition of the heartwood of all points below and into the next 16-foot log above the first. A sporophore situated well up on the trunk may be taken to indicate undesirable material throughout the main part of the tree. Little need be said concerning the presence of more than one sporophore. It will be observed that the largest usually has smaller ones above and below it.

This generally indicates that the largest sporophore marks the area of greatest decay and that the decay has traveled both ways. In any case, trees bearing more than one sporophore situated some distance from each other are not merchantable and should be cut down and burned or fire-girdled.

The presence of sporophores on the tree is an indication of a fairly advanced stage of decay throughout a good portion of the tree. On the other hand, the absence of sporophores does not always indicate soundness. A few cases may occur where the tree is so old in decay that the sporophores have died and fallen away. The discoloration of the bark at the point of attachment or the hole left by the rotting



FIG. 4.—An old sporophore of *Echinodontium tinctorium* on hemlock. Top view, showing the zonation and the relation to intensive decay.

branch may readily be noted. The old sporophores, which have a remarkable resistance to decay, may be observed on the ground at the base of the tree. Pounding on the tree is a fairly accurate method of determining soundness, down to a particular stage of rot. In doubtful cases, remarkably accurate results may be obtained by pressing the ear firmly against the tree while pounding. Previous to this, the bark should be removed over a small area in order to secure an uncushioned sounding point.

Probably the most practical method for the average marking officer, in the absence of visible defects, is the presence of red color a half inch or so within the dead branch stubs. This reddish coloration of the rot *E. tinctorium* is an index of an advanced stage, and its appearance so far out on the dead branch as to be detected by merely breaking

off the branch is a sure sign of the typical rot within. The red color may not show at the base of every branch, in which case several may be examined. If the red color does not show after the knot has been opened with the corner of an ax, the branch may still show a yellowish dry-rot or the usual flinty consistency of a naturally pruned branch has given way to a loosened condition of its annual rings. This may be taken to indicate an initial stage of the rot only at this point, however, for the heartwood of the tree may be entirely decayed, due to the fungus having entered at another point. Knocking off



FIG. 5.—Sale area after logging (private logging operations), showing defective hemlocks left standing, a waste of valuable material and a menace to the surrounding forest. Note the “conks” on the trunks.

a few dead branches with an ax does not require much time and is a very good method to use in such a case.

In general, individual trees growing under suppressed conditions or a type developing in a close stand can be expected to disclose a large amount of decay, especially when growing on moist river-bottom sites. The slope type of stand must be judged more carefully, and it is often the case that in vigorous stands an infected tree will yield the first two logs sound while the upper portion of the trunk will be in the last stages of decay. Under such conditions sounding by blows will not be found practicable, but the presence high on the trunk of many branch stubs, dead branches, and sporophores will

always indicate the true condition. Moist sites of various slopes and exposures are generally found to produce a greater development of decay, and invariably the older trees in such stands are badly infected. This is indicated by the data secured from lumbermen given in the pages that follow. The early formation of branch stubs through the premature dying of the lower crown due to overshadowing can always be depended upon as an indication of existing decay, and it will usually be found that the center of infection is located in that portion of the trunk bearing the largest number of dead branches or branch stubs. The presence of many branch stubs, the presence of branch stubs showing unmistakable rot colorations, the appearance and number of sporophores, many injuries (including frost cracks), old age, and unmistakable signs of reduced vigor are all very reliable indications upon which a marking officer may learn to base his judgment for the determination of decay in western hemlock.

GENERAL CHARACTERISTICS OF THE ROT.

The spores of *Echinodontium tinctorium* upon germination penetrate the host mainly through the dead broken branches or branch stubs (figs. 6 and 7). This has been confirmed by the data taken in the study of the relation of injuries to decay. A few infections are traceable to fire and logging scars, frost cracks, or other injuries. In a few instances, on areas other than those upon which data were secured, it has been found that the burls on hemlock caused by *Razoumofskya tsugensis* were points of infection.

The hyphæ on germinating follow the central nonresinous heartwood zone of the branch stubs and continue inward to the main heartwood of the tree (fig. 8), spreading more or less uniformly up and down the trunk from the point of infection. The decay is char-



FIG. 6.—Cross section of a young hemlock, showing heart-rot at a whorl of branch stubs. In this case there are five dead branch stubs, all of which were possible agencies in conveying the disease into the heartwood.

acterized in hemlock and grand fir by its uniformity in occupying the heartwood (figs. 4 and 8). In alpine fir the rot in cross section takes on a somewhat stellar development, due principally to the concentration of the hyphæ along certain of the medullary rays.

In badly decayed living trees it is invariably the case that the rot not only occupies the entire heartwood of the trunk but the heartwood of the branches as well (fig. 9), extending in some of the larger ones a distance of several feet,¹ causing the formation of sporophores at some distance from the trunk.

The advance rot of *Echinodontium tinctorium* is very difficult of detection and unless accompanied by small brownish discolorations



FIG. 7.—Section of hemlock, showing a branch stub as a means of first infection of heart-rot. The decay has commenced spreading into the heartwood from the end of the branch tissue.

or by reddish or brownish streaks can not be detected without a very close examination. In the early stages of the decay the wood assumes a faint yellowish, spongy texture. Sometimes this stage is intensified by the presence of small, hardly discernible brownish areas, which later develop into the typical rot. The extension of the advance

rot beyond the typical rot varies greatly according to the conditions. Some accurate data are at hand to determine the average height of the advance rot beyond the typical rot. Such data will be found very useful to scalers in determining the amount of cull to deduct from the gross scale in order to cut out all the advance rot which might later develop into the crumbly decay complained of by dealers in hemlock lumber. Meinecke² states that in the white fir (*Abies concolor*) of this region the advance rot produced by *E. tinctorium* extends about 2 to 6 feet beyond the typical rot. From the data collected on more than 200 hemlocks of all ages and sizes an extension of 1 to 5 feet has been found to be general. A single figure

¹ Weir, J. R. Destructive effects of *Trametes pini* and *Echinodontium tinctorum*. In *Phytopathology*, v. 3, no. 2, p. 142. 1913.

² Meinecke, E. P. Forest-tree diseases common in California and Nevada, p. 52. 1914. Published by U. S. Department of Agriculture, Forest Service.

can not be used to express this relation, since it varies with all the factors influencing the progress of the decay. As a rule, it would be safe to add to the linear estimate of the cull $1\frac{1}{2}$ feet beyond the last recognizable punky area or area showing the slightest yellowish discoloration. The typical rot (figs. 4, 8, and 9) is readily recognizable and has a characteristic reddish brown to brownish yellow color, often spotted with areas of a more vivid rust color and occasionally showing streaks or lines of a dark red to reddish brown hue. Its texture is very pronounced and this, combined with its color, forms the basis for the scaler's common name for the defect "stringy brown-rot." In the last stages of decay the heartwood is entirely disorganized, giving place to large cavities in the butt logs and sometimes in the logs above. The stringy nature of the rot can be readily seen in this stage and also in the ends of logs badly but not hollow

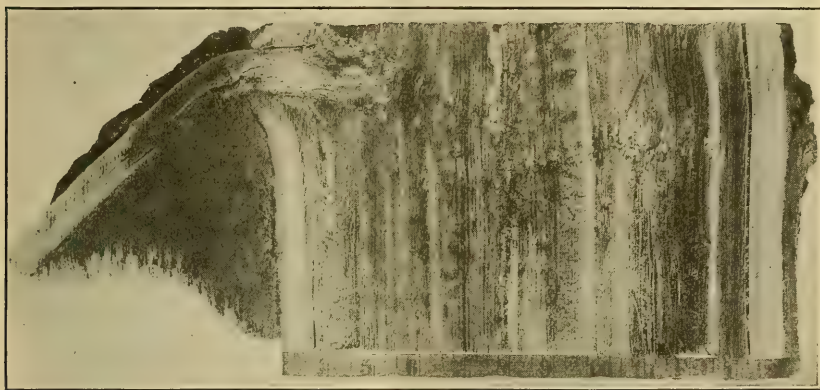


FIG. 8.—Longitudinal section of an old sporophore of *Echinodontium tinctorium* on hemlock, showing its relation to branch stubs.

rotted, especially in the grass-stubble effect (figs. 4 and 10) produced by the sawing. The brick-red color of the sporophores is often found distributed through the typical rot and in the branch stubs in the final stages of decay.

AREAS STUDIED AND FIELD METHODS USED.

The areas selected for study lie in the drainage basin of the Priest River in Idaho. Throughout this region western hemlock is rather evenly distributed, extending downward from the subalpine zone into the upper limits of the yellow-pine zone. The species attains its best development on damp north slopes and is found greatly suppressed when growing as an understory in the dense bottom stands.

One of the factors promoting the development of forest-tree fungi of the region is the high annual precipitation. The dry periods of

the year are comparatively short, so that the sporophores of perennial fungi may never at any time be entirely dried out. During the late fall, extending into December and coincident with the formation of new fruiting surfaces of the Indian-paint fungus, rain falls almost constantly. The average annual precipitation is between 20 and 30 inches, increasing rapidly with elevation, reaching a maximum of more than 40 inches in the higher slopes.

In the spring of 1915 investigations were begun on the river-bottom and slope sites of the Priest River valley in Idaho. The general altitude of the region is about 2,450 to 2,500 feet. The meanderings of the Priest River in former times created a number of

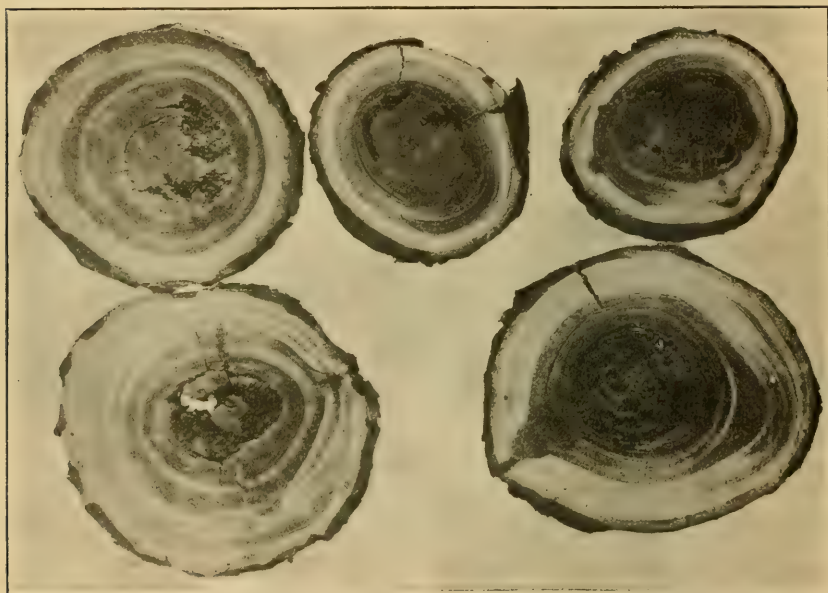


FIG. 9.—Cross sections of a hemlock branch in which heart-rot extended 10 feet out from the trunk, showing how the larger branches may be affected.

swamps and bayous, which are filled with water during the greater part of the year. The interlying areas are poorly drained.

The whole region is one of dense forests, composed of western white pine (*Pinus monticola*), western red cedar (*Thuja plicata*), western larch (*Larix occidentalis*), Engelmann spruce (*Picea engelmanni*), Douglas fir (*Pseudotsuga taxifolia*), western hemlock (*Tsuga heterophylla*), grand fir (*Abies grandis*), western yew (*Taxus brevifolia*), western birch (*Betula occidentalis*), and cottonwood (*Populus trichocarpa*).

The soil is a moist sandy loam, with much alluvial material and not well drained on the river-bottom sites. There is a great depth of humus, litter, and needles. On the above-described site, ten

separate plats were laid out, comprising 5.7 acres. The river-bottom and slope types were first selected for investigation, for the reason that at these elevations and under the existing conditions grand fir and hemlock are heavily diseased. The plats represented a variety of age classes, mixtures, and successions.

The investigations on grand fir and hemlock were carried out simultaneously, but the data on the former are reserved for a future report. The influences of site and elevation on the distribution and amount of decay were considered, and the data were consequently divided according to the two sites indicated. In order to get the percentage of rot of hemlock and grand fir, a clean cut of these species



FIG. 10.—Section through a trunk of hemlock, with an old sporophore attached. The stringy nature of the heart-rot and the grass-stubble effect due to sawing are both characteristic.

was made. The trees were bucked in such lengths (16 feet and shorter) as to determine the transverse and longitudinal extent of the decay; also the point at which the decay was greatest. That section of the trunk containing the upper extension of the decay was fully dissected, in order to determine the exact upper limit. The diameter of the rot at each log end was measured and recorded. The rot in each tree was measured in detail. A full analysis of the stump was also made. A uniform stump height of 18 inches was maintained throughout. The age of the tree was determined at this point, and four years added to the age at the stump, giving the entire age.¹ Before the trees were felled, full notes on the external

¹ This average age at stump was secured by taking data on a number of seedling hemlocks in the same stand and determining the age corresponding to the stump height of the felled trees.

appearance relative to environment, etc., were recorded. Each tree was designated by a number. Altogether, 201 trees of western hemlock were cut on the ten areas, and about an equal number of grand fir. The hemlocks considered in this study are numbered from 1 to 201. No selection of trees was practiced, but all trees on the areas laid out were cut.

Aside from a few cases of secondary decay, the cause of which could not be definitely determined from a chemical and anatomical study of the rot alone, the occurrence on hemlock of the more common fungi of the associated species was practically nil. In a few cases the rot of *Trametes pini* and *Polyporus schweinitzii* was found in hemlock, but since the merchantable parts of the same trees were wholly decayed by *Echinodontium tinctorium*, all decay of the species on the areas is attributed to the latter. This is equivalent to saying that practically 100 per cent of all cases of decay in living hemlock were due to *E. tinctorium*. This is by no means an unusual condition for the region. In fact, the finding of any other fungus working as a first agent of decay in hemlock is a rarity.

METHODS USED IN PRESENTING DATA.

The methods used in preparing the data for presentation and comparison are the result of an attempt at standardizing such factors as, in ordinary field observations, are usually determined by an ocular method not involving exact measurements. Any attempt at standardization of such factors as are included under "Seriousness of injury," "Degree of vigor," or "Crown rating" is bound to meet with difficulties. So long as the same standard is used consistently throughout the work, a slight amount of arbitrary standardization will not in the least reduce the value of the results.

The total volume of the tree, less the stump, inside of the bark was first secured in cubic feet by means of the paraboloid formula,¹ $V = (BH \div 2)$, and the table of basal areas.² The diameter (inside of the bark) at the stump was used to secure the above figure. The total volume of rot in the tree, less the stump, was secured in cubic feet by a similar method. As an experiment to determine the shape of the rot column, the outlines of the rot column of several infected hemlocks were plotted on coordinate paper. It was found that these rot outlines conformed closely to the general outlines of the trees. It was also found that the formula used to secure the volume of rot more nearly included all the rot found within the trunk than did the Smalian method. The dissection of the trees and the plotting of a few of them on coordinate paper showed that the formula as

¹ Graves, H. S. Forest Mensuration, ed. 1, p. 88. New York, London, 1906.

² Graves, H. S. Op. cit., p. 430.

here used allowed for such rot as was to be found outside of a straight line drawn from points on the rot sections appearing at both ends of the logs and such rot as was found extending outward from the heart-wood along the branch whorls. The advance rot is included in the total rot in every case. The rot percentage was secured from the two given volumes.

The basis for classifying the seriousness of injury is given as follows:

0 = No injuries.

x = 1 to 4 branch stubs, no frost cracks, and very few miscellaneous injuries (less than 2).

xx = 5 to 9 branch stubs, one frost crack, and a superficial blaze, logging scar, or other slight injury.

xxx = 10 to 15 branch stubs, not more than 2 frost cracks, deep blazes, logging scars or fire scars, and slight lightning injury.

xxxx = 15 or more branch stubs, more than 2 frost cracks, and heavy injuries (injured and broken top, severe lightning, and other injuries).

The grouping of trees according to the crown class has, in general forestry practice, been almost entirely done by ocular estimate. In the present study the four gradations of the crown class were taken from Forest Service Bulletin 61¹ and were used with the crown size in composing the standard for crown rating. The actual size of the crown and the crown class are used to determine this rating. The crown sizes in square feet (length by width of crown) for each age class are grouped together, the largest and smallest sizes compose the extremes of the large and the very small crown divisions, respectively, the remainder ranging in order of size between these two. The group is then divided into four equal classes: Large, average, small, and very small. The individual trees are then given their respective crown rating according to the following outline:

(1) Crown size, large. (Crown class 1.)

(2) Crown size, average. (Crown class 2.)

(3) Crown size, small or one sided. (Crown class 3.)

(4) Crown size, very small. (Crown class 4.)

The vigor of a tree is indicated by the size and condition of its crown and by the favorableness or unfavorableness of the position it occupies, as well as by the narrowness of the sap zone and the fineness of its annual rings. The injuries which the tree receives during the course of its development also play an important part in influencing its vigor. The rating for vigor has therefore been based upon the following three factors, in the order of their importance: (1) Width of average ring in sap, (2) crown rating, and (3) the degree of injury. This rating for vigor at least comes nearer registering the true condition than a mere ocular estimate. The fixing of the standard or average width (as in oo where the width is 0.12 to 0.19 inches) was

¹ Terms used in forestry and logging. U. S. Dept. Agr., Bur. Forestry Bul. 61, 53 p. 1905.

secured from a careful checking of all the data and from the table by Hanzlik and Oakleaf ¹ giving the average annual diameter growth for western hemlock as obtained under average conditions in western Washington.

Rating of Vigor.

- o=Thrifty.—Width of average ring in sap 0.20 inches and up; 1 in crown rating; classed as 0 or x under degree of injury.
- oo=Fair.—Width of average ring in sap 0.12 to 0.19 inches; 2 in crown rating; classed as x or xx under degree of injury.
- ooo=Poor.—Width of average ring in sap 0.04 to 0.11 inches; 3 in crown rating; classed as xx or xxx under degree of injury.
- oooo=Low.—Width of average ring in sap 0.03 inches and less; 4 in crown rating; classed as xxx or xxxx under degree of injury.

Other methods specially adapted to develop certain data will be found explained under the headings which follow.

The size of the average ring in the sap is the most important factor in the vigor determinations. The injury ratings (as *x* or *xx*) in the *oo* vigor class are intended to give a certain leeway in so far as the injuries found on the trees are concerned. Many trees have an *x* rating for injury, yet the vigor as indicated by crown size and by width of average ring in sap indicates a thrifty tree. A similar leeway is given the other vigor classes.

INFECTION AGE.

In studying the life history of a particular type, such as the river-bottom type of western hemlock, it becomes evident in the course of the work that certain age classes within that type represent a definite stage in the development of decay. This has been brought out by Meinecke ² in his work on white fir (*Abies concolor*). The factors governing the entrance and development of a fungus in its host tend to determine a certain average age which indicates the age of first infection, an age at which the stand is most liable to first infection by the fungus and below which the infection rarely occurs.

Judging from Meinecke's ³ discussion of the age of infection, he defines it as the age at which "infection rarely leads to more than negligible decay unless the tree is handicapped by quite unusually severe conditions." An attempt has here been made more accurately to define this average age. The youngest trees only were used and of these only those which were infected. This age is briefly outlined as the average age of the youngest trees open to first infection by the fungus.

¹ Hanzlik, E. J., and Oakleaf, H. B. Western hemlock; its forest characteristics, properties, and uses. In *Timberman*, v. 15, no. 12, 1914, p. 25-33, tab. 3.

² Meinecke, E. P. Forest pathology in forest regulation. U. S. Dept. Agr. Bul. 275, p. 47-48. 1916.

³ Meinecke, E. P. Op. cit., p. 48.

Table I represents all the trees of the 41 to 62 age class, inclusive, taken from plats classed in the river-bottom and southwestern-slope types. The 15 and 9 youngest trees of each site (river bottom and southwestern slope), respectively, were used to secure an average age representing the infection age. This age for each tree was secured by means of the formula, $A_1 = A - (V \div V_1)$, where A_1 equals age of first infection, A equals age of tree, V equals volume of rot of the tree, and V_1 equals the average annual increase in rot volume for the age class in which the tree is included. This last figure is obtained from Table II. It was attempted to use the first 15 trees of the southwestern-slope type. This gave an infection age of 70 years but included trees as old as 99 years, while the oldest tree of the river-bottom type was only 62 years. In using 9 trees, the oldest tree of the slope site is 75 years, giving a more equal comparison.

TABLE I.—Data relating to the infection age of heart-rot in western hemlock on plats of the river-bottom and southwestern-slope types.

Age.	Tree No.	Volume of rot.	Approximate value for $V \div V_1$.	Probable age of infection. ¹	Number of infected trees (basis).
		Cubic feet.	Years.	Years.	
River-bottom type: ²					
46 years.....	82	0.07	2	44	13
48 years.....	83	.03	1	47	
54 years.....	84	.06	2	52	
54 years.....	85	.68	19	35	
55 years.....	86	.32	9	46	
55 years.....	87	0	0	0	
56 years.....	88	.36	10	46	
57 years.....	89	.27	8	49	
57 years.....	90	.19	5	52	
58 years.....	91	.44	13	45	
60 years.....	92	0	0	0	
61 years.....	93	.59	17	44	
62 years.....	94	1.11	32	30	
62 years.....	95	1.13	32	30	
62 years.....	96	.12	3	59	
Average.....				44.5	
Slope type: ³					
54 years.....	1	0	0	0	4
57 years.....	2	.07	4	53	
60 years.....	3	0	0	0	
62 years.....	4	0	0	0	
67 years.....	5	0	0	0	
70 years.....	6	.17	9	61	
72 years.....	7	.51	26	46	
75 years.....	8	.11	6	69	
75 years.....	9	0	0	0	
Average.....				57.3	

¹ Formula: $A_1 = A - (V \div V_1)$. $V_1 = 0.035$.

² Site description.—River-bottom flat, very moist; soil not well drained; stand very dense. Almost all individuals of the tolerant species, such as western hemlock and grand fir, were overtopped or suppressed.

³ Site description.—Southwestern slope, partly flat; old-age class of a white-pine type in which the hemlock has become a climax species; soil fairly moist and well drained; stand not overcrowded.

Table I shows that the average infection age for the river-bottom type is 44.5 years and for the southwestern-slope type 57.3 years. It thus appears from a comparison of the results shown in this table

that the average infection age for the slope type is higher than that for the river-bottom type. This is undoubtedly due to the fact that the environmental factors in the river-bottom type are more favorable to early attack by the fungus. Crowded stands, much shade and suppression, and a higher percentage of atmospheric and soil moisture all presumably contribute to the earlier infection in the stands situated along the river bottoms.

It is to be understood that the figures as given in the tables that follow are not to be taken as absolute. The small numerical basis for some of the data, especially in Table I and part of Tables II and III, and other sources of unavoidable error, make it plain that the figures given are to be interpreted as indicative of the true conditions and not as an absolute analysis. The general tendencies must first be ascertained and the methods for determining them developed before absolute figures are presented.

TABLE II.—Average annual increase in the volume of heart-rot in infected western hemlock trees of the several age classes, on plats of the river-bottom and southwestern-slope types.

Age class.	Average age.	Interval between age classes.	Average volume of rot (cubic feet).		Number of infected trees (basis).
			As measured.	Annual increase between age classes.	
River-bottom type:	Years.	Years.			
46 to 56 years.....	52	10	0.27	0	6
57 to 62 years.....	60	8	.55	.035	7
63 to 70 years.....	66	6	.82	.045	32
71 to 80 years.....	75	9	2.23	.16	39
81 to 90 years.....	86	11	3.62	.13	19
91 to 102 years.....	95	9	4.04	.05	7
104 to 126 years.....	114	19	4.21	.01	6
All age classes.....			2.25	.07	116
Slope type:					
54 to 70 years.....	62	16	.12		2
72 to 75 years.....	74	10	.31	.02	2
90 to 99 years.....	94	20	1.42	.06	6
101 to 120 years.....	110	17	14.31	.81	6
134 to 160 years.....	149	38	16.89	.07	9
162 to 179 years.....	172	23	19.16	.10	11
184 to 200 years.....	193	21	46.62	1.31	12
207 to 225 years.....	216	23	46.56	a .62	13
226 to 306 years.....	254	38	73.43	.71	12
All age classes.....			24.30	.46	73

a Interpolated.

RELATION OF DECAY TO SITE AND TO AGE.

Western hemlock, which ranges in decay from 50 to 100 per cent of trees infected in some localities and quite generally so over large areas where the species occurs in nearly pure stands, may be entirely free from its principal disease (heart-rot, caused by *Echinodontium tinctorium*) in some regions.

In order to determine the distribution of *Echinodontium tinctorium* and the extent of the damage produced by it as influenced by various environmental factors, a series of questions was prepared and submitted to the timber and mill owners in all parts of the Northwest. In response to a total of 151 letters sent out, 44 replies dealing with hemlock were received. A certain number of the replies were confined to grand fir alone. The replies to the questions were prepared by experienced scalers and cruisers, to whom the writers desire to express their thanks for the careful attention and willingness shown to further the progress of the investigation. In most cases the "conks" (figs. 1, 2, 3, and 4) of the fungus chiefly responsible for the decay in hemlock for the region were sent by the recipients of the letters. In practically every instance the fungus was *E. tinctorium*. Many of the northwestern regions not covered by these letters were visited; hence it was possible to gain a fairly accurate knowledge of the range and destructiveness of this disease along with the data on other phases of the study. Since the questions given out dealt with a variety of factors, the information thus obtained is submitted under the various sections of this paper covering the particular point under discussion. Four of the questions concerned the influence of site on the distribution and prevalence of decay.

The belief that conditions of soil, moisture, exposure, and altitude greatly influence the distribution and prevalence and the amount of decay caused by a particular fungus in the forest is supported by the data thus obtained. Out of 44 different observations covering a great range of territory, including the entire economic range of the tree in the United States, only three observers report a uniform distribution of decay in hemlock for all conditions. All other replies indicate great differences in the amount of heart-rot as influenced by soil, slope, and elevation. The topography and soil of those regions from which a uniform condition of defect is reported are so uniform in themselves that no great variation could be expected. The question of the influence of the site on the prevalence of the fungus *Echinodontium tinctorium*, it appears, depends on the moisture condition of the soil and its porosity and not upon soil quality. The fungus may occur on hemlock growing on any type of soil, but occurs to a greater extent on trees growing on wet, undrained sites. This is found to be true at any elevation, showing very clearly that the excessive moisture conditions of the site are highly favorable to the development of the principal attacking fungus. The answers indicate that the soundest hemlock is usually associated with a rich, well-drained soil. In wet, shallow soil the root system can not attain its normal position but must stay near the surface. If the soil is sufficiently loose to enable the roots to penetrate deeply, but is undrained,

as in semiswamp, bottom sites, decay is prevalent and a retardation of growth also results. No relation between the composition of the soil and the prevalence of the fungus has been observed. Hemlock growing on lime, sand, or clay soils as a base for the regular humus layer exhibits no greater proclivity to fungus attack than do other species. Of the total answers received, 41 stated definitely that the least defective hemlock was found at the upper elevations and slopes and upon well-drained soils. The most defective stands were en-

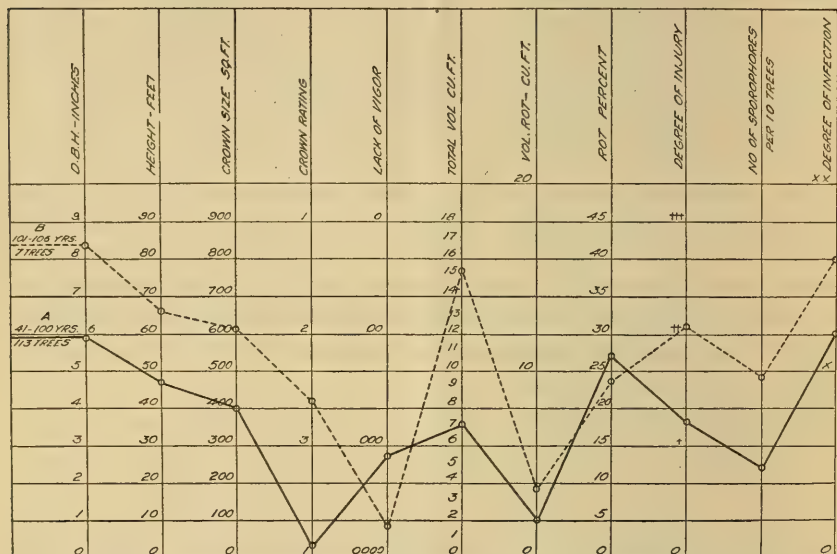


Fig. 11.—Diagram showing the relation of various factors to the age classes of western hemlock on plots of the river-bottom type.

countered at lower elevations, on flats and bottom sites, and upon poorly drained soils.

As the tree grows older it reaches a certain period in its life at which its vigor seems to have reached its maximum, after which time the vitality of the tree ebbs. This is often spoken of merely as old age and is the resultant lowering of vigor due to the increased unfavorable environment of its surroundings. Many factors enter into this relationship, competition with younger and sturdier trees for light, water, and food being the principal ones. Not the least of these factors is the effect of cumulative injuries received throughout its life. Many writers on forest pathology have expressed this opinion, and the data following (Table IV) convey a like conclusion. Von Schrenk¹ states that "it has been pointed out that as trees grow older they become

¹ Schrenk, Hermann von. Some diseases of New England conifers: A preliminary report. U. S. Dept. Agr., Div. Veg. Phys. and Path. Bul. 25, p. 51. 1900.

more liable to insect and fungus attack. An old tree has many vulnerable points, such as old branches and wounds," and naturally these injuries open the tree to more and greater infections. Hartig¹ does not believe that old age is a natural inherent condition, but says: "In itself, the feebleness of old age is not a natural condition attributable to internal causes. The older a tree is, so much the more numerous are the dangers through which it has had to pass, and so much the greater is the number of its injuries and wounds through which parasites and saprophytes can find an entrance into its inte-

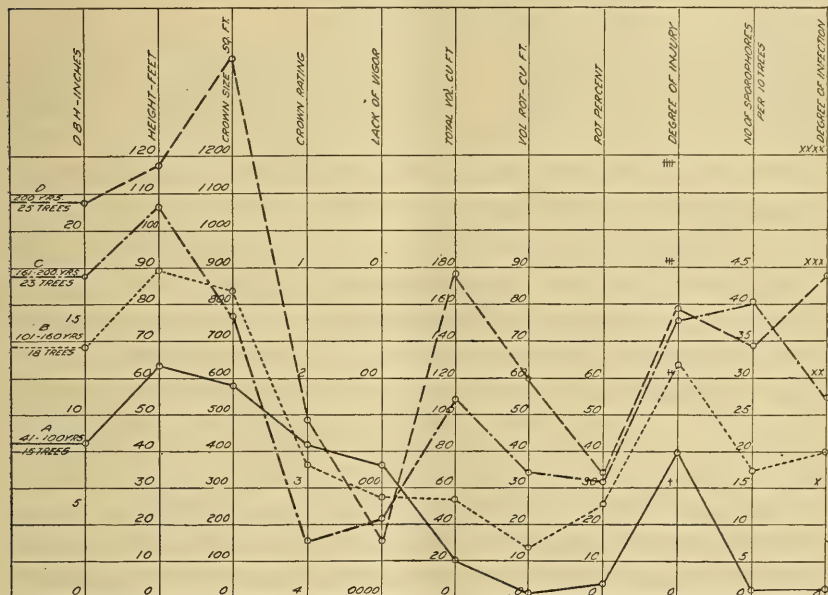


FIG. 12.—Diagram showing the relation of various factors to the age classes of western hemlock on plots of the southwestern-slope type.

rior." From the data secured by questions sent to a large number of lumbermen in the Northwest, it was found that a majority of the answers received indicated that the older age classes of hemlock were very much more defective than the younger. Möller² has shown that, with the increase of age in stands infected with *Trametes pini*, there was a corresponding increase in the percentage of trees infected, and the data given in Table III and figures 11 and 12 also show plainly that with increasing age there is a definite increase in the amount of decay.

¹ Hartig, R. Textbook of the Diseases of Trees. Translated by William Somerville, p. 7. London and New York, 1894.

² Möller, A. Über die Notwendigkeit und Möglichkeit wirksamer Bekämpfung des Kiefernbaumschwammes *Trametes pini* (Thore) Fries. In Ztschr. Forst. u. Jagdw., Jahrg. 36, Heft 11, p. 677-715, 2 pl. (partly col.). 1904.

TABLE III.—Averages computed from field data relating to heart-rot in western hemlock based upon trees of the several age classes on plats of the river-bottom and south-western-slope types.

Type and age classes.	Number of trees (basis).	Diameter breast high.	Height.	Crown size (height by width).	Crown rating.	Lack of vigor.	Volume (cubic feet).		Rot percentage.		
							Total.	Of rot.	For class.	For stand.	
										Total.	Infected trees.
River-bottom type:		<i>Inches.</i>	<i>Feet.</i>	<i>Square feet.</i>	<i>Degree.</i>						
41 to 100 years.	113	5.9	47.0	400.0	3.9	3.1	7.1	1.9	27.1	26.6	96.7
101 to 160 years	7	8.4	65.7	609.5	2.6	3.4	15.3	3.6	23.6		
Slope type:											
41 to 100 years.	15	8.4	62.6	574.2	2.6	2.8	19.8	.62	3.1	30.8	90.1
101 to 160 years	18	13.6	88.9	833.3	2.8	3.1	52.6	13.20	25.1		
161 to 200 years	23	17.5	106.0	761.6	3.5	3.3	107.6	33.50	31.1		
201 years and over.....	25	21.5	117.0	1,458.6	2.4	3.5	175.5	59.40	33.8		

From the viewpoint of the natural increase in heartwood due to larger size, etc., coincident with age, it is presumed that the amount of decay would increase proportionately. The figures obtained in the case of the southwestern-slope type show this to be not only true in this respect, but the proportion of the volume of decay to the total volume of the tree is also much higher. In the river-bottom site (Table III) the average volume of rot increases from 1.9 cubic feet in the 41 to 100 year age class to 3.6 cubic feet in the 101 to 160 year age class. In the southwestern-slope type (Table III) a better comparison between age classes can be made. Here a definite increase in rot volume from the 41 to 100 year age class to the 201 year and older age class is evident. Table II also shows an irregular increase in the average annual increase in rot volume between age classes, though the general trend of the figures in Table II shows a gradual increase from the younger to the older trees up to the age class 81 to 90 years, after which a gradual decline is noted. This fact might possibly reflect the rate of growth of the tree and therefore of the heartwood and indicate a dropping off in rot activity simultaneously with a slowing up of the annual growth.

RELATION OF DECAY TO VIGOR, CROWN RATING, SIZE, AND VOLUME.

Decay in western hemlock is the main factor of depreciation outside of fire. No other destructive agency operates upon this tree to cause so much waste and none is so difficult to control. The preceding data have shown how the tree, especially when growing in river-bottom sites, is subject to attack by this fungus at an early age, and for the youngest age classes the river-bottom type shows a greater average volume of rot than the southwestern-slope type. In the data secured from lumbermen of the Northwest it is found that a

high rate of decay is general in western-hemlock and grand-fir stands and especially so in low, poorly drained bottoms. The hemlock and also the grand fir reacts more favorably in the sites where the factors concerned in the growth of the tree are less favorable to the advance of the attacking fungus.

The relation which such factors as vigor, crown rating, size, and volume bear to the inception and progress of decay has never been thoroughly demonstrated. A difficult part of this task lies in obtaining comparable figures to indicate the rating for lack of vigor, the crown rating, the degree of infection, and the degree of injury. By standardizing these factors on numerical data, a basis for comparison has been secured. In the first part of Table III are arranged the averages of 120 trees, taken from the various plats worked as growing on the river-bottom site. In this table the total height represents a measurement from the ground to the tip of the tree. The crown size is given as the product of the height of the crown by the width. The crown rating and lack of vigor are determined from the field sheets, according to the standard outlines given. Similarly, the total volume and the volume of rot determine the rot percentage. In the column "Lack of vigor," the figures represent the relative numerical values, determined in the following manner: All trees (18) of the 101 to 160 age class were grouped together (second part of Table III). Three of these trees had a lack of vigor represented by 00, 10 trees by 000, and 5 trees by 0000. $3(00)$ equals $6(0)$, $10(000)$ equals $30(0)$, and $5(0000)$ equals $20(0)$, which gives a total of $56(0)$. This figure divided by 18 gives $3.1(0)$, which is indicated by 3.1. This gives a numerical basis for the relative values of lack of vigor in plotting the graphs. A similar method was applied to the data in the column under crown rating, and the results secured were used in the plotting of the graphs (figs. 11 and 12). This method was also used in the "Average degree of injury" column in Table IV and in plotting points for the graphs in figures 11 and 12.

The process was applied to the trees of the various plats which were growing upon the southwestern-slope sites, and the resulting data are arranged in the second part of Table III. Pathological graphs were then constructed from each of the two parts of Table III, using all the factors concerned and arranging the units in such a manner as to secure the least confusion in following the individual graphs. In the graph in figure 11, constructed from the figures relating to river-bottom plats in Table III, the first points to be noted are that the diameter, height growth, crown size, total volume, and volume of rot all increase with the increase in age. This is found to be true also in figure 12 (with the exception of crown size), which graphically expresses the data given for plats of the southwestern-slope type in Table III. In searching for those factors most prominent in their

relations to the degree of infection and included within the first eight factors of the graph, there is apparently no one which stands out. The factors of height, diameter, crown size, total volume, and lack of vigor show increase with increased age, so that no special importance can be attached to these in so far as any one directly influences the rate of decay. The data herein given are not sufficient proof that vigor is the one outstanding factor influencing decay; since vigor is expected to decrease with increased age, the parallelism of increased decay and decreased vigor can not be interpreted as a direct influence exerted by vigor. No doubt vigor plays an important part in the speeding up or slowing down of the rate of decay in a tree, if only this relation could be determined accurately and definitely.

The total rot percentage for the entire stand of the bottom type is 26.6, as compared with 30.8 per cent for the slope type. This slight difference in the percentage of total rot for the two types (where a greater difference might be expected) is significant and is no doubt due to the fact that under each site are grouped all the trees, ranging from the youngest to the oldest. A comparison of the percentages of infected and uninfected trees for the two sites shows a striking difference in results from different methods of presenting the amount of infection in a stand. In the river-bottom type, 97 per cent of the trees were infected and 27 per cent of the wood decayed. In the slope type, 90 per cent of the trees were infected and 31 per cent of the wood decayed. A comparison of these figures indicates that ease of infection is the factor in which the bottom type exceeds the slope type and the rate of spread of decay in the trunk is less speeded by bottom location, if at all. The latter belief seems to be borne out by the fact that the rate of spread in the bottom type must necessarily have been slow, since the stand was composed of comparatively young trees of small heartwood content.

In the slope type the environment is favorable to the full development of tree growth, with an environment equally unfavorable to the development of fungi. The reverse is true of the river-bottom type. This is evidenced by the facts brought out in Table III (figs. 11 and 12), which show that decay is more pronounced in the river-bottom type than in the other. The graphs also show that in the 41 to 100 year age class (Table III) the conditions for the best development of the health of the trees were far below those for the 101 to 160 year age class.

RELATION OF DECAY TO INJURY AND TO SPOROPHORES.

The relation of injuries to decay in respect to furnishing entrance points for infection has been accepted with little opposition, and in many instances in culturing fungi it has been found that the opening

of the protective tissues of the host plant was necessary in order to produce infection. A portion of the field data was obtained with the principal object of determining the part played by the degree of injury. All injuries were noted as to size, height on tree, side of tree affected, total number, and condition (whether healed or not healed); whenever possible the age when the injury was inflicted and the time taken to heal were also noted. A special effort was made to determine, if possible, the particular injury causing the original infection. This was generally taken to be at the point on the trunk where the oldest sporophore appeared. Table IV gives summaries for the river-bottom and southwestern-slope types, respectively, based upon an age-class division of the trees.

TABLE IV.—*Relation of injuries causing heart-rot to the age and to the total stand of western hemlock trees on plats of the river-bottom and southwestern-slope types.*

Type and age class.	Infection traced to—								Uninfected trees.		Average degree of injury.	Number of trees.
	Branch stubs.		Frost cracks.		Broken tops.		Miscellaneous injuries.					
	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.	Number of trees.	Per cent.	Number.	Per cent.		
River-bottom type:												
41 to 100 years.....	103	91.2	1	1.0	3	2.6	2	1.7	4	3.5	1.19	113
101 to 160 years.....	7	100.0	0	.....	0	.....	0	.....	0	.....	2.05	7
Total.....	110	92.5	1	.1	3	2.5	2	1.6	4	3.3	1.14	120
Slope type:												
41 to 100 years.....	9	60.0	1	6.7	0	.....	0	.....	5	33.3	1.3	15
101 to 160 years.....	12	66.6	0	.....	1	5.7	2	11.1	3	16.6	2.1	18
161 to 200 years.....	16	70.0	1	4.0	3	13.0	3	13.0	0	.....	2.5	23
201 years and older.....	22	88.0	0	.....	2	8.0	1	4.0	0	.....	2.6	25
Total.....	59	72.8	2	2.6	6	7.4	6	7.4	8	9.8	2.1	81

^a Windfall scars.

Table IV shows that by far the greatest percentage of infection was attributed to branch stubs (figs. 6, 7, and 8).

This amounted to 92.5 per cent in the river-bottom type and 72.8 per cent in the slope type for the total stand in each type. Broken tops come second, and miscellaneous injuries, such as windfall and logging scars, etc., reached a percentage of 7.4 in the slope type and 1.6 in the river-bottom type. Grouped under miscellaneous causes were such injuries as blazes, logging, windfall and fire scars, lightning, etc., and a considerable amount of sapsucker injury. The first infection was not attributed to a certain injury unless the development of a sporophore on it (fig. 2) showed this to be the most apparent point of infection. The relative degree of injury as determined upon a basis of age class is shown in figures 11 and 12, taken from Table IV under the head of "Average degree of injury." This shows an increase

in degree of injury with an increase in the degree of infection and with increased age. With increase in age the cumulative chances for infection due to injuries of all kinds, and especially to branch stubs, increase appreciably, and it is but natural that the older trees bearing many injuries and a high degree of injury should show an equally high degree of infection.

The two types of stand compared on the basis of the amount of injury are found to vary but little in the general relation between the degree of infection and the degree of injury. In both types the groups of higher rot percentage also show a higher degree of injury, and similarly the groups of lower rot percentage show a smaller degree of injury. In both sites the infections traced to branch stubs bore the largest percentage and the frost cracks the smallest. Broken tops in both instances came second in importance.

In the southwestern-slope type (Table IV), the percentage attributed to broken tops was larger than in the river-bottom type (Table IV), due to the more exposed location and to the older stand. Infections traced to branch stubs in the slope type equaled 72.8 per cent of the total, while in the river-bottom type it equaled 91.5 per cent. It would appear that in spite of the younger age class the river-bottom type developed more infection-producing branch stubs than the other. A reason for this may be found in the fact that the crowded, suppressed condition of the river-bottom stand was much more favorable to the infection of branch stubs than the other more open type of stand. The high proportion of branch-stub infections to injury infections can be partly explained by the fact that the trees of the river-bottom type, being younger, had fewer injuries.

In the slope type the largest amount of injury was found in the oldest age class (201 years and older), and in the river-bottom type it was also found in the older age class (101 to 160 years). In the slope type 10 per cent of the trees were uninfected, and in the river-bottom type a much smaller percentage (3) was uninfected, showing by this comparison a more favorable environment for the attacking fungus in the river-bottom sites.

The slope type exhibited more frost cracks, broken tops, and miscellaneous injuries to the stand than the river-bottom type, which is due partly to the older age and partly to the more exposed situation. The wind plays an important part in both the formation of frost cracks and in the broken-top condition of many of the trees. It was particularly interesting to note that most of the oldest and largest frost cracks were found to have formed in the hollows between the root spurs. This seems to be more general in the slope type, where the exposure to high winds and the height of the trees (in connection with low temperature) appears to play an important part in their

formation. The swaying of the trees by the wind when the low temperature has set up a stress within the tissues of the lower trunk would cause the cracks to form at right angles to the swaying movement and in the root-spur hollows, where the least resistance to splitting was to be encountered. The swaying of the tree alone sets up varying forces of strain and rupture in the lower part of the tree, and when the tissues are contracted or prevented by low temperatures from adjusting themselves, a frost crack eventually occurs.

Sporophores of fungi, if they develop at all, appear after a certain period has elapsed from the time of first infection. This period, up to the present time, has not been determined for most of the xylophilous fungi, at least not for *Echinodontium tinctorium*. Such determination would involve a considerable amount of careful inoculation work upon trees absolutely free from fungous infection, which in the case of wood-destroying fungi would extend over a period of several years. The relation which sporophores bear to the development of decay in the host and to the degree of infection can more easily be determined. A careful field study of the tree in question with reference to recording all possible data relating to the sporophores has developed several interesting facts. Little work has been done along this line tending to give actual figures as a basis for conclusions. The data collected are grouped under the two parts of Table V for the river-bottom and slope types, respectively. Under the heading "Position on tree," the sporophores were grouped to indicate whether the northerly growing sporophores were more numerous than those growing on the southerly side of the tree. The remaining columns in Table V are self-explanatory with the exception of the column headed "Relative position along trunk." This refers to the vertical position of the largest sporophore with respect to the other sporophores on the same tree. For example, tree No. 50 had a total of five sporophores, of which the third one from the ground was the largest. This condition was expressed by the figures 3-5, indicating that the position of the largest sporophore was in the center of the group. This method was used throughout, and the resulting figures were used to determine whether the largest sporophore was found more commonly in the center or toward either end of the group.

The river-bottom type with reference to its sporophore data (Table V) is in general very similar to the slope type. Out of a total of 119 trees, 70 (59 per cent) were sporophore-bearing trees. On these 70 trees a total of 149 sporophores were found, of which 131 (88 per cent) were living and 18 (12 per cent) were dead, giving an average of 1.8 live sporophores to a tree and 1 dead sporophore to every 4 trees. These figures show a much larger percentage

of live sporophores than those of the slope type. Almost all (96 per cent) of the largest were living, which was equally true of the sporophores in general. The average height from the ground is 8.7 feet. The northwest to north-northeast grouping held 53 per cent of the total sporophores, the southwest to south-southeast grouping 27 per cent, the east 9 per cent, and the west 11 per cent. Most of the sporophores are grouped on the northern aspect of the trunks, with a smaller percentage on the southern. Upon dividing the sporophores into groups corresponding to the eight principal points of the compass, it was found that most of them (23 per cent) were on the northwest side, the next largest on the south (18 per cent), and the smallest number on the southeast (3 per cent).

The figures in Table V, river-bottom type, relative to the number of sporophores are plotted in figure 11 and show the relation between the degrees of infection and the number of sporophores. To avoid the awkwardness of using such an expression as "1.3 sporophores" in the diagrams, it was thought proper to term this factor "Number of sporophores per 10 trees" and use the same figures after multiplying each by 10. This does not alter the comparative value of the figures. These data and the pathographs indicate how the increase in the number of sporophores keeps pace with the increase in the degree of infection.

In the southwestern-slope type (Table V), out of a total of 81 trees 54 (67 per cent) bore sporophores in varying numbers. These 54 trees carried a total of 210 sporophores, of which 141 (67 per cent) were alive and 69 (33 per cent) were dead, giving an average of 2.6 live and 1.2 dead sporophores per sporophore-bearing tree. More than half (60 per cent) of the largest were living. These data indicate that the number of sporophores increases with increased age and with increase in the degree of infection as expressed by the rot percentage. This holds true for all the age classes except the oldest, which is found to have a smaller total number of sporophores and a smaller number per 10 trees than the 161 to 200 age class. This may be due to the fact that the maximum sporophore production has been reached in the 161 to 200 age class and to the further fact that on old trees the older sporophores are often found to have dropped to the ground. An average of all the figures relative to the vertical position of the largest sporophore gave a figure which placed it at or very near the middle point. This would seem to indicate that the decay spreads more or less in both directions up and down the trunk from the point of original infection; consequently the sporophores are produced on either side of the largest as the decay progresses. This is, of course, not true in every case, but the average condition is found to be such.

TABLE V.—Summary of sporophore data relating to heart-rot of western hemlock trees on plats of the river-bottom and southwestern-slope types.

Age class.	Sporophores.										Infection traced to—								
	Number of trees (basis).	Number of trees bearing sporophores.	Number alive.	Number dead.	Total number.	Average number per tree.	Largest.				Smallest.	Position on tree.							
							Average age.	Condition.	Size.	Relative position along the trunk.		Average height.	Northwest to east.	Southwest to east.	East.	West.	Branch stubs.	Broken tops.	Frost cracks.	Miscellaneous injuries.
River-bottom type:	112	64	118	14	132	1.2	6.6	3	9 by 6 by 4.	Lower.	1 by 1 by 1.	8.3	67	38	12	15	2	0	1
41 to 100 years	a 7	6	13	4	17	2.4	10.0	0	8 by 6½ by 3.	Middle.	3 by 2½ by 1½.	13.1	12	3	1	1	0	0	0
101 to 160 years	119	70	131	18	149			67	3 9 by 6 by 4.		1 by 1 by 1.		79	41	13	16	2	1	1
Total Number.		58.8	87.9	12.1	2.1		c 7	95.7	5 by 3½ by 2½.	(d)		8.7	53	27	9	11	17	0.9	0.9
Average per sporophore-bearing tree.			1.80	b .25				All.					(e)	All.		All.			
Slope type:																			
41 to 100 years	15	1	1	0	1	.07	9.0	1	8 by 5 by 3.	Middle.	3 by 3½ by 1.	9.5				1	8	1	
101 to 160 years	18	11	21	10	31	1.70	8.5	9	9 by 5 by 5.	do.	3 by 3 by 2.	30.6	14	12	0	5	13	1	2
161 to 200 years	23	20	63	29	92	4.00	15.1	10	16 by 8 by 8.	do.	3 by 3 by 2.	40.4	24	24	12	16	16	4	2
201 years and older	25	22	56	30	86	3.40	12.8	13	11 by 11 by 5.	do.	3 by 2 by 2.	45.3	26	21	16	23	23	2	
Total Number.	81	54	141	69	210			33	16 by 8 by 8.	Middle.			80	57	28	45	60	7	4
Average per sporophore-bearing tree.		66.6	67.1	32.9	4.0		f 13	61.1	7 by 6 by 4.	Middle.		39.9	38.1	27.1	13.3	21.5	82.2	9.6	5.4
			2.6	1.3				All.					(e)			All.	All.		

a Sporophore data lost on one tree, which therefore was not included.

b One to every four trees.

c Average age of largest sporophores.

d Between middle and lower.

e All northerly.

f Average age of largest sporophores.

The distance from the ground of the largest sporophore ranges from 4.5 feet in the case of younger suppressed trees to 78.5 feet in the case of a large 300-year-old veteran. The average height indicated 39.9 feet. The grouping of the sporophores in respect to their cardinal positions on the tree gave some very interesting figures. The largest number of the sporophores (38 per cent) was found in the northwest to north-northeast grouping, 27 per cent in the southwest to south-southeast, and 21.5 and 13.5 per cent in the west and east groupings, respectively. Upon dividing the sporophores into groups corresponding to the eight principal points of the compass, it was found that 25 per cent were on the north side, the next largest on the west (21 per cent), and the smallest number on the southwest (4 per cent). The data for the slope type show the largest number on the northerly side of the tree. No such overwhelming percentage was secured as in the work of Möller,¹ who assembled data on the sporophores of *Trametes pini* (Brot.) Fr. and found that 45.8 per cent of the sporophores appeared on the west side of the tree and 89.4 per cent on the westerly side. This westerly side included all sporophores listed in the north, south, and west columns.

Figure 12, the southwestern-slope type, represents in the respective column the sporophore data taken from Table V. The same relation is found to exist between the degree of infection and the total number of sporophores as is found in the river-bottom type. The number of sporophores per 10 trees ranges from 13 in the 41 to 100 age class to 24 in the 101 to 160 age class, exhibiting a considerable increase between the two. In the slope type a similar rate of increase can be noted, which is constant between all the age classes except the two oldest.

THEORY OF INFECTION.

Suppression caused by shade combined with a crowded condition of root spacing as well as crown spacing tends to reduce vigor appreciably. A poorly drained soil having a large amount of soil moisture is another factor to be considered in this connection.

Upon the vigor of a tree depend all its vital functionings, its ability to enlarge and elevate its crown toward better lighting, to secure raw material and manufacture food, to compete with its neighbors, to quickly heal wounds, and to resist attack by fungous enemies. The predisposition or inherent susceptibility of a tree to disease is not considered a sufficient cause for the extensive attack and development of a fungus in that tree. It is believed that low vigor or a

¹ Möller, A. Über die Notwendigkeit und Möglichkeit wirksamer Bekämpfung des Kiefernbaum schwammes *Trametes pini* (Thore) Fries. In Ztschr. Forst. u. Jagdw., Jahrg. 36, Heft 11, p. 677-715, 2 pl. (partly col.) 1904.

natural weakness in healing injuries, producing resin, etc., combined with environmental factors is responsible for the intensive and extensive fungous activity within this species of tree. At the same time it must be borne in mind, especially in the case of hemlock, that such a natural trait as the absence of any great amount of protective resin must be considered as playing an important part in the entrance of the disease. The foregoing data have clearly shown that one fungus is responsible for almost the entire amount of heart-rot found in western hemlock, that the river-bottom type exhibits more decay than the other (comparing the youngest age class), that this type also exhibits a remarkably early decay, and that as a whole a large amount of heart-rot is found in hemlock at early periods in its life.

Dense stands growing in moist, poorly drained soils develop a large number of suppressed or low-vigor trees. This is more commonly the case when the stand is overtopped by older trees of other species. The low vigor due to the overshadowing of the lower crown causes the early and numerous formation of shade-killed branches. These in time produce branch stubs which are believed to be responsible for most infections by *Echinodontium tinctorium*. The shading of the crown, especially the lower crown, not only causes the eventual formation of branch stubs but produces a moisture and shade condition favorable to the germination and entrance of the fungus. As a theory of infection for hemlock types, this is corroborated by the fact that in thinnings made by cutting out the more merchantable species the secondary crowns formed rapidly and vigorously by an enlargement and thickening of the regular crown. This fact, coupled with the observation that very few living sporophores were found 10 years after the thinning, strengthens the theory.

DISCUSSION OF RESULTS.

As a preliminary to the discussion of the main points brought out in the foregoing pages, it is essential to review briefly the main silvicultural characteristics of the tree in question. It will then be easier to point out the importance of the various factors influencing decay and to arrive at certain conclusions regarding the action of the fungus *Echinodontium tinctorium* during its life history on the host.

The western hemlock, as indicated by its distribution, requires a cool and moist climate for its development, and an important fact in this connection is its splendid maximum development along the western slope of the coast ranges, where it receives an annual rainfall of from 70 to 100 inches.¹

¹ Allen, E. T. The western hemlock. U. S. Dept. Agr., Bur. of Forestry Bul. 33, p. 10. 1902.

Its moisture requirements seem to be the principal limiting factor of its distribution, since it is found growing on a variety of soils. Its altitudinal range extends from sea level in Alaska, British Columbia, Washington, and Oregon to an altitude of 6,000 feet, and in Idaho and western Montana it is found at a maximum altitude of 5,000 feet. It is always at its best in cool moist draws or north slopes. Regions with a relatively high humidity favor its development, although at some of the higher altitudes the humidity is much less than in the bottom-land sites.

A very tolerant species, it is found to thrive in Idaho and Montana in the white-pine type, generally in a mixed stand. Referring to its tolerance, Sudworth¹ says it is "very tolerant of shade throughout life, especially in seedling stages. In later life vertical light is necessary for best growth. Allowed overhead light, it recovers remarkably well from long suppression and renews rate of growth. Prolonged suppression in dense shade greatly checks growth. It thrives in cool, open, humid places with abundant soil moisture."

No natural thinning takes place under normal conditions, and in mixed stands the pruning of the lower branches is a slow and imperfect process. Shade causes the lower branches of the crown to die, and these remain on the trunk until broken by wind, windfalls, or other causes. This condition leaves the tree with a large number of branch stubs open to infection by fungous spores.

Hemlock in its green condition contains 40 to 60 per cent of its own dry weight of moisture,² a relatively large amount compared to the other trees of the region. This fact has a direct bearing upon the action of the fungus in the heartwood and accounts for the water-logged condition of the base of the tree which is often encountered in stands growing on poorly drained soils.

In summing up the points brought out by this study the most pronounced results are found in the variations in the action of the decay in the two types studied. A glance at the plat descriptions given for each type (Table I) will show the variation in slope and exposure as well as the marked difference in soil and atmospheric moisture. The river-bottom type, growing as a dense suppressed stand on a heavy undrained soil in close proximity to the river and to its numerous sloughs, presupposes its greater susceptibility to the attack of the fungus. In the absence of trees of an older age class it can only be assumed that the rot percentage would increase with age. The fact that the rot percentage in the older age class was lower does not invalidate this assumption in view of the small number of trees it

¹ Sudworth, G. B. *Forest trees of the Pacific Slope*, p. 95. 1908. Published by U. S. Department of Agriculture, Forest Service.

² Hanzlik, E. J., and Oakleaf, H. B. *Western hemlock; its forest characteristics, properties, and uses.* In *Timberman*, v. 15, no. 12, 1914, p. 25-33, tab. 3.

contains. The total percentage of infected trees as well as the total rot percentage of this type in comparison to the slope site bear out this statement (Table III). The relation of moist sites to the degree of infection of a stand has been noted by Hartig,¹ who says: "The climatic conditions peculiar to a given district may render it especially liable to outbreaks of certain diseases. Thus, in alpine districts proximity to lakes and narrow valleys specially predisposes to certain fungoid diseases, because the moist air of such places favors the fructification of fungi in a high degree." The loss of vigor due to the unfavorable environmental conditions and principally due to suppression by shade is responsible to a certain extent along with other factors in the rapid and universal spread of the decay on this site. Meinecke² states: "The relative extent of decay by *Echinodontium tinctorium* is far greater in slow-growing, suppressed white firs than in thrifty ones." And in discussing the susceptibility of hemlock to injury Hanzlik and Oakleaf³ state: "Broken branches and injuries to the bark account largely for the spread of conk (*Trametes pini*) and the stringy brown-rot (*Echinodontium tinctorium*), these being more abundant in overmature stands and in suppressed stands overtopped by mature growth."

That on the river-bottom type the trees are decayed at an earlier age, is brought out by a comparison of the data given. The river-bottom type in comparison with the slope type exhibits not only extensive decay at an earlier age and a younger age of infection but a larger number of branch stubs and sporophores for similar age classes for the stand. The data secured from the lumbermen of the north-western region also aid in determining the fact that hemlock is more defective on lower elevations, on bottom or flat sites, and on poorly drained soils.

In making use of pathological data in the determination of pathological cutting ages for a stand; the rot percentages as given here for separate age classes of the stand are of some value. With the rot percentages as a basis (indicating the ratio of the rot volume to the total volume of the stand for each age class), the forester can determine a cutting age for that stand, using all the economic and silvicultural factors to aid him in a correct determination. The average annual increase in rot volume between age classes can also be used to advantage in determining the rapidity of increase in rot volume. Forest pathology can thus serve to furnish pathological data for particular stands, which data can be applied by the practical forester

¹ Hartig, R. Textbook of the Diseases of Trees. Translated by William Somerville, p. 10. London and New York, 1894.

² Meinecke, E. P. Forest-tree diseases common in California and Nevada, p. 27. 1914. Published by U. S. Department of Agriculture, Forest Service.

³ Hanzlik, E. J., and Oakleaf, H. B. Op. cit.

in a solution of such forest-regulation problems as are appreciably influenced by the presence of decay in the stand. When once the forester reaches the point in his calculations upon a proposed sale where he can determine a certain rot percentage as the maximum to be considered in a stand in order to secure the required amount of sound material at a minimum cost, with this rot percentage as a basis it will be comparatively easy to compute the cutting age of that stand.

METHODS OF CONTROL.

The methods of control applicable to such types as are here under discussion can be little other than extensive. The foregoing data, owing to the small number of trees included in some of the age classes and to apparently unavoidable errors, are not to be taken as exact in determining the cutting age but are given merely as an aid to this determination. Intensive control methods can not be applied to logging operations where extensive logging methods are practiced. Methods such as can be readily incorporated into the usual routine of logging operations and conforming to the practice of the Forest Service are the only ones which can hope to fill the need for forest sanitation among the all-practical lumbermen and foresters. Intensive control can be practiced to a limited extent only upon such sales areas as warrant the additional cost.

The control of wood-destroying fungi is not a matter comparable to the curative treatment of human disease, but is solely dependent for its success upon prevention. With few exceptions there is no help for a stand after it is once attacked by the fungus; hence, if preventive measures are to be effective they must precede the infection, or at least precede the period when the production of spores endangers the remaining healthy trees. There are several methods applicable to the hemlock type, and these can be grouped under two heads, sanitation clauses in timber sales ¹ and pathological rotations. Under the first come such suggestions as girdling, killing by burning of infectious cull material and piled brush, thinning, and the direct cutting and burning of infected material. Under the second appear such methods based upon a study of the area in question as would lead to a cutting cycle aiming to secure the maximum amount of sound material with a minimum risk of future infection and at a minimum of cost. Each particular sale area has its individual variations affecting the pathological condition of the stand. The species in the mixture and the relative percentage of each, the slope and exposure, the moisture conditions, the cost of logging, the value of the species in the stand (in fact, all the environmental and economic factors) have to be taken into consideration before an attempt can be made to determine a method of control.

¹ Meinecke, E. P. Op. cit., p. 62. 1914.

A pathological survey of sales areas made with the object in view of determining the best method of incorporating sanitation clauses or of establishing pathological cutting ages would be an important step toward a practical and effective means of reducing the total amount of good timber going to waste every year in our forests. Girdling by the ax as a method of removal of infected trees left standing on a sale area is not to be recommended as an effective means of control. If the situation allows of no better method, then the girdling should proceed, the utmost care being exercised in severing all the transporting tissues. The recuperative ability of hemlock in regard to the healing of wounds is very great (fig. 13). Merely cutting a cleft in the outer sapwood, leaving the chip in

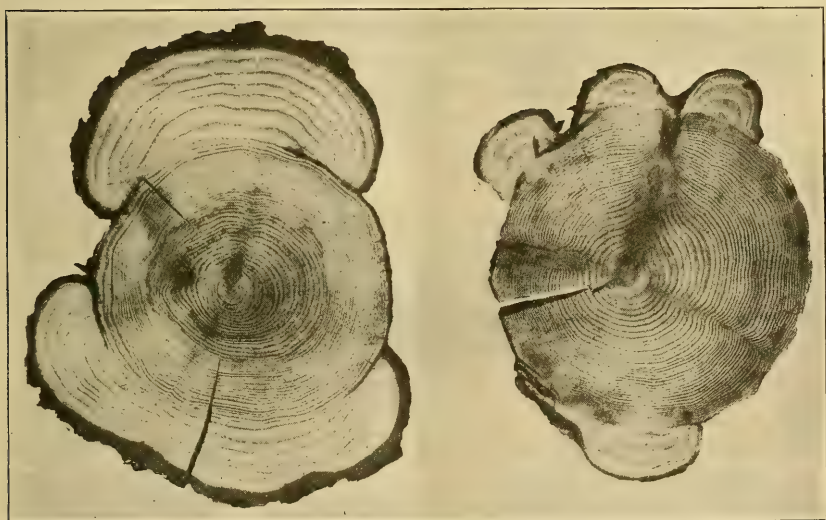


FIG. 13.—Cross sections of grand fir (at left) and western hemlock (at right), showing the result of imperfect girdling by the use of an ax.

place, will not suffice. The wound is very apt to heal, and even if it does not the tree may continue to live for years because the transporting tissues have not been actually severed. It is to be remembered that the wood of hemlock, owing to its nonresinous nature, probably retains its ability to conduct water and food substances longer than that of many of its associates; hence it will be found necessary to insist upon thorough girdling. Some notable instances of the longevity of even thoroughly girdled hemlocks and firs have come to notice in which the trees continued to live for five to eight years although the bark and part of the wood had been removed entirely around the tree for a foot or more. Trees under the shock of this wounding will sometimes produce as much seed in the year following as during several years of normal life. This point is im-

portant in connection with the girdling sometimes done for the purpose of removing seed trees of undesirable species.

In view of the need of a rapid destruction of fungus-infected trees, viz, those that may not be considered safe to leave on sales areas, there is much in favor of burning the trees severely and allowing them to stand. Girdling trees by fire is an old and successful practice. There should be sufficient loppings from the other merchantable trees that when piled about the base of the hemlocks and burned will effect their death without much injury to the forest soil or to the seeds of desirable species which may be embedded in the soil.

Thinnings whenever conformable to the conditions of the sales areas are of importance in greatly increasing the vigor and therefore presumably the ability to resist fungus attack in the remaining infected trees, and apparently reducing the number of viable and spore-producing fruiting bodies produced.

Under certain conditions where it is found practicable, a method of control by fire can be very effectively used. It has been observed that in cases where the down logs of hemlock were left in a sufficiently shaded and moist situation sporophores of *Echinodontium tinctorium* were developed, which were a source of infection to the remaining stand. The cutting of all infected trees and the piling and burning of all infectious cull material along with the brush will not only remove the fungus-infected wood but will prevent the formation of infection-spreading sporophores.

SUMMARY.

Western hemlock, a tree subject to prejudice by lumbermen and now beginning to find its place in the lumber markets, is abundantly distributed throughout the northwestern United States and western Canada. †

It is found to be subject to a large percentage of decay, which is partly accountable for the prejudice against it.

Echinodontium tinctorium E. and E., the Indian-paint fungus, is responsible for practically all the decay in standing timber of western hemlock, causing a stringy brown-rot of the heartwood which extends to all parts of the tree.

In general, the sites and associations of western hemlock are favorable to the development of decay, and the moisture relation seems to play an important part in this respect. The absence of large quantities of resin, the tolerant habit of the species, the early and abundant formation of branch stubs, and the large number of spores produced yearly—all these are important factors in the rapid and extensive development of decay in the stand.

The fungus enters mainly through branch stubs. Frost cracks play a minor part as first-infection injuries. From the point of first infection, apparently coincident with the largest sporophore, the decay extends up and down the heartwood until all the susceptible heartwood is attacked. The extent of decay is found to increase with age. A high degree of injury, large numbers of sporophores, low vigor, and smaller crown sizes appear to develop more or less parallel with the increase in decay.

The environmental factors in the river-bottom type are more favorable to the early and extensive development of decay. A large percentage (97) of the total trees of the northern Idaho plats examined were found to be infected. Of 10 trees less than 60 years old and 3.5 inches in diameter breast high, 9 were infected.

The environmental factors in the southwestern-slope type are less conducive to early decay. The maximum development of the fungus is not reached until the stand is old.

A large number of sporophores are produced on both sites, the river-bottom site on a comparison basis of age class showing the greater number. The 48 trees over 160 years of age bore an average of 3.7 sporophores per tree.

Pathological cutting ages based upon data secured by thorough pathological surveys and adjusted to the economic factors concerned, if applied to all stands of hemlock, would aid greatly in checking the spread of the disease and would determine the cutting age of the stand before the increase in rot became too great for economic logging. In the present study this could be applied to the slope type only, since the trees of the river-bottom type are all below merchantable size.

A rigid sanitation clause inserted in all timber-sale contracts involving western hemlock should be aimed principally at the destruction by fire of all infectious cull material as well as all infected trees left standing. Girdling by the ax is not recommended.

These two control methods, when adapted to the situations they best serve, will pave the way to the sanitation of the western hemlock stands as well as other types of forests in the Northwest.

THE PRESIDENT TO THE FARMERS OF AMERICA.

[Extracts from President Wilson's message to the Farmers' Conference at Urbana, Ill., January 31, 1918.]

The forces that fight for freedom, the freedom of men all over the world as well as our own, depend upon us in an extraordinary and unexpected degree for sustenance, for the supply of the materials by which men are to live and to fight, and it will be our glory when the war is over that we have supplied those materials and supplied them abundantly, and it will be all the more glory because in supplying them we have made our supreme effort and sacrifice.

In the field of agriculture we have agencies and instrumentalities, fortunately, such as no other government in the world can show. The Department of Agriculture is undoubtedly the greatest practical and scientific agricultural organization in the world. Its total annual budget of \$46,000,000 has been increased during the last four years more than 72 per cent. It has a staff of 18,000, including a large number of highly trained experts, and alongside of it stand the unique land-grant colleges, which are without example elsewhere, and the 69 State and Federal experiment stations. These colleges and experiment stations have a total endowment of plant and equipment of \$172,000,000 and an income of more than \$35,000,000, with 10,271 teachers, a resident student body of 125,000, and a vast additional number receiving instruction at their homes. County agents, joint officers of the Department of Agriculture and of the colleges, are everywhere cooperating with the farmers and assisting them. The number of extension workers under the Smith-Lever Act and under the recent emergency legislation has grown to 5,500 men and women working regularly in the various communities and taking to the farmer the latest scientific and practical information. Alongside these great public agencies stand the very effective voluntary organizations among the farmers themselves, which are more and more learning the best methods of cooperation and the best methods of putting to practical use the assistance derived from governmental sources. The banking legislation of the last two or three years has given the farmers access to the great lendable capital of the country, and it has become the duty both of the men in charge of the Federal-reserve banking system and of the farm-loan banking system to see to it that the farmers obtain the credit, both short term and long term, to which they are entitled not only, but which it is imperatively necessary should be extended to them if the present tasks of the country are to be adequately performed. Both by direct purchase of nitrates and by the establishment of plants to produce nitrates, the Government is doing its utmost to assist in the problem of fertilization. The Department of Agriculture and other agencies are actively assisting the farmers to locate, safeguard, and secure at cost an adequate supply of sound seed.

The farmers of this country are as efficient as any other farmers in the world. They do not produce more per acre than the farmers in Europe. It is not necessary that they should do so. It would perhaps be bad economy for them to attempt it. But they do produce by two to three or four times more per man, per unit of labor and capital, than the farmers of any European country. They are more alert and use more labor-saving devices than any other farmers in the world. And their response to the demands of the present emergency has been in every way remarkable. Last spring [1917] their planting exceeded by 12,000,000 acres the largest planting of any previous year, and the yields from the crops were record-breaking yields. In the fall of 1917 a wheat acreage of 42,170,000 was planted, which was

1,000,000 larger than for any preceding year, 3,000,000 greater than the next largest, and 7,000,000 greater than the preceding five-year average.

But I ought to say to you that it is not only necessary that these achievements should be repeated, but that they should be exceeded. I know what this advice involves. It involves not only labor but sacrifice, the painstaking application of every bit of scientific knowledge and every tested practice that is available. It means the utmost economy, even to the point where the pinch comes. It means the kind of concentration and self-sacrifice which is involved in the field of battle itself, where the object always looms greater than the individual. And yet the Government will help and help in every way that is possible.

It was farmers from whom came the first shots at Lexington, that set aflame the Revolution that made America free. I hope and believe that the farmers of America will willingly and conspicuously stand by to win this war also. The toil, the intelligence, the energy, the foresight, the self-sacrifice, and devotion of the farmers of America will, I believe, bring to a triumphant conclusion this great last war for the emancipation of men from the control of arbitrary government and the selfishness of class legislation and control, and then, when the end has come, we may look each other in the face and be glad that we are Americans and have had the privilege to play such a part.

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BULLETIN No. 723



Contribution from the Bureau of Entomology
L. O. Howard, Chief
and the Federal Horticultural Board, C. L. Marlatt, Chairman

Washington, D. C.

August 30, 1918

THE PINK BOLLWORM¹ WITH SPECIAL REFERENCE TO STEPS TAKEN BY THE DEPARTMENT OF AGRICULTURE TO PREVENT ITS ESTABLISHMENT IN THE UNITED STATES.

By W. D. HUNTER,

In Charge of Southern Field Crop Insect Investigations and Member of the Federal Horticultural Board.

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HISTORICAL.

In 1842 the superintendent of the Government cotton plantations at Broach, India, sent specimens of a very destructive cotton insect to the distinguished English entomologist, W. W. Saunders. The specimens were described as a new species, *Depressaria* (now *Pectinophora*) *gossypiella*, by Mr. Saunders in a paper presented to the Entomological Society of London on June 6, 1842 (9).² This is the first published record concerning the insect which is now attracting so much attention in the principal cotton-producing countries of the world.

For 61 years after the publication of Saunders's description no published statement regarding the pink bollworm was issued. In 1904, however, an article was issued by J. Vosseler (10) regarding the great injury done by the insect in German East Africa. Within

¹ *Pectinophora gossypiella* Saunders; order Lepidoptera, family Gelechiidae.

² Numbers in parentheses refer to "Literature cited," p. 27.

the next few years several additional articles dealing with the problem caused by the pest in German East Africa appeared. In 1909 D. T. Fullaway (5) published an account of the pink bollworm and its relation to cotton culture in the Hawaiian Islands, stating that it appeared to have been introduced from India within a very few years.

Only a few more or less technical papers were published from 1909 to 1913. Since the latter date a considerable literature has been built up, consisting largely of papers emanating from Egypt, where the pest has attracted increasing attention.

ORIGINAL HOME.

The original home of the pink bollworm is probably India and possibly Southern Asia generally, and its original host plants were the wild and cultivated cottons of that region. If this natural range of the insect extended to Africa it must have been limited to Central Africa and at least it did not extend to the Nile Valley region where cotton has been an important cultivated crop for a century or more. The occurrence of the insect in Egypt is apparently traced definitely to large shipments of seed cotton or imperfectly ginned cotton from India in 1906-7, and the spread of the insect from the points in the lower Delta near Alexandria, where this cotton was sent for ginning, throughout the Delta, and ultimately throughout Egypt, is so circumstantial as to leave no doubt as to the entry of the insect at that time into Egypt. With the first occurrence of the insect in Egypt it was confused more or less with other insects commonly found in cotton bolls in that country, and this confusion led to a statement by Dudgeon (4) that this insect had probably been in Egypt for many years. The careful investigation of the situation and determination of original points of infestation and spread by expert entomologists in the employ of the British and Egyptian Governments have fully disproved this early surmise and pointed out the circumstantial introduction of the insect into Egypt as noted.

As already noted, the pink bollworm has been recorded as a cotton pest in India since 1842, and the original report made by the Superintendent of the Government Cotton Plantation at Broach, India, is of sufficient importance to be given in full, as follows:

The inclosed is an insect which was very destructive to the American cotton which was sown here (Broach) on light alluvial soil. The egg is deposited in the germen at the time of flowering, and the larva feeds upon the cotton seed until the pod is about to burst, a little previous to which time it has opened a round hole in the side of the pod for air, and at which to make an exit at its own convenience, dropping on the ground, which it penetrates about an inch, and winds a thin web in which it remains during the aurelia state. Curious enough, the cotton on the black soil was not touched by it. The native cotton is sometimes affected by it.

The significant thing in the paragraph is the statement that the insect was very destructive to the American cotton and that "*native cotton is sometimes affected by it.*" The fact that the American cotton was much more affected than the native varieties is in accord with the general experience with imported plants in relation to native plant pests, and with introduced pests in respect to native plants. The American variety was apparently unresistant in comparison with the native cottons of India which, with little doubt, had been long associated with this pest and which have developed a certain amount of resistance.

The later records of this insect show that it was reported from India on several occasions prior to 1900 or about that period, and those records determined also its occurrence eastward through Burma, Siam, and the Philippines, long prior to what was undoubtedly its original entry into Egypt in 1906-7.

The insect was first noted in Egypt in 1911, and the first severely infested field, one near Alexandria, was noted in the year following (1912). The increase of the damages from this insect in Egypt has been steady since 1912 and this in spite of very laborious and expensive control operations enforced by the Egyptian Government.

The present distribution, therefore, of the pink bollworm is reasonably traceable to spread from Southern Asia in comparatively recent years. The possible exception is German East Africa, and even there the natural explanation of its occurrence is its recent introduction with cotton imported from India, although there is the possibility, already noted, that the natural range of the insect may have included Central Africa and that the African infestation may therefore have come from such native stock.

PRESENT RANGE.

With the exception of two infestations in Texas, which it is hoped will be stamped out, the known range of the pink bollworm is as follows:

East Africa, West Africa, Egypt, Nigeria, Sudan, Zanzibar, India (very generally), Bengal, Ceylon, Burma, Straits Settlements, China, Philippines (Luzon), Hawaii, Brazil, and Mexico. There is also a record from Japan, although this may be erroneous. At any rate it is not confirmed by Prof. Kuwana, government entomologist, according to a statement published by Fullaway (5). The introduction of the pink bollworm into Brazil and Mexico is very recent, and the available records show very clearly how it was accomplished. As these are of special interest at the present time, the particulars will be given.

The information from Brazil comes through Mr. Edward C. Green, superintendent of the Cotton Department of the Ministry of Agricul-

ture, who has published a very full statement on the subject (8). During 1913 Mr. Green made a trip of inspection through the greater portion of the cotton-producing area in Brazil. Special attention was paid to the seed, not only in the fields but in the ginneries, and no infestation was found. In 1916, however, another trip showed that the pink bollworm was present over wide areas in the States of Parahyba, Rio Grande del Norte, and Ceara. It seems that in the years 1911, 1912, and 1913, the Government of Brazil imported nine tons of Egyptian cotton seed. This seed was not fumigated as it was not suspected that any injurious insect was likely to be carried by it. A test for germination showed 89 per cent viable. It is altogether likely that a percentage of the unviable seeds were those attacked by the pink bollworm. All of this seed was sent to agricultural inspectors in various States and by them was distributed further throughout the cotton-growing districts.

There can be no doubt that the general establishment of the pink bollworm in Brazil was due to the importation of the Egyptian seed, and that incalculable losses to the country could have been avoided if proper quarantine precautions had been taken.

In Mexico the pink bollworm was introduced in 1911. During that season two importations of Egyptian seed were made. One consisted of 125 sacks and was planted near Monterey; the other, of 6 tons, and this was planted in the vicinity of San Pedro in the Laguna. From what is known of the abundance of the pink bollworm in Egypt in 1911 it is probable that both shipments of seed were infested and that both of them contributed to the present infestation in Mexico. It is true that cotton culture has not been continued in the vicinity of Monterey, but the crop of Egyptian cotton produced there in 1911 attracted considerable attention and much of the seed was shipped to the Laguna.

The work of determining the spread of the pink bollworm in Mexico was greatly facilitated by the cooperation of the Mexican Government. The Minister de Fomento, Sr. Pastor Rouaix, Sr. José Duvallon, Director de Agricultura, and Prof. Julio Requelme Inda of his department, showed the greatest interest in the matter as soon as the presence of the pink bollworm in Mexico was known. Sr. Duvallon dispatched a special representative, Sr. Alfonso Mada-riaga, to Northern Mexico, where he spent some months in making examinations in the Laguna. His findings corroborated in every way the discoveries made by Mr. Busck.

Very recently specimens of the pink bollworm have been received from China. They were collected by Mr. H. H. Jobson, who at the present writing (May, 1918) has just returned from China. Mr. Jobson's notes are as follows:

The collection which I have secured from the seed room of one of the ginneries in Shanghai and from the fields at Tungchow, about 12 hours' ride by boat up the river from Shanghai. The infestation is more or less general throughout China; however, there may be some small areas where it is not present. A majority of the cotton grown within a radius of 100 miles of Shanghai is shipped into that port before being ginned, and from evidences found at the ginning establishments there is no doubt but what all those regions are infested. In fact, the larvæ are so numerous that by going into the seed room of the gins a person may secure any number of them within a very short time, as they may be seen crawling around over the seed and on the walls.

PRESENT DISTRIBUTION IN MEXICO.

As far as absolutely definite evidence shows, the pink bollworm is confined to three localities in Mexico, one of which is the Laguna district, a valley isolated by mountain ranges about 200 miles from the Texas border. The Laguna, in which the bulk of the total Mexican crop is produced, consists of about 1,200 square miles of land. Mr. August Busck, on a trip to Mexico in the early part of 1917, obtained samples of cotton seed from 40 of the estates in that region. Thirty of these samples were found to be infested and later records indicate infestation on ranches from which no insects in the seeds were received. In short it is evident that through the shipment of cotton seed from one part of the Laguna to another and possibly through the flight of the insect, the pink bollworm has become generally established there. Although the distribution of the pest is naturally irregular at the present time, it is certain that it will become uniform in the course of a few years, and that most energetic steps must be taken by the planters to control or eradicate the insect. Other localities known to be infested in Mexico are Allende, about 40 miles south of Eagle Pass, and the Trevino ranch, immediately opposite Del Rio. In both cases the infestations were the result of the receipt of seed from the Laguna.

NATURE AND AMOUNT OF DAMAGE.

The pink bollworm affects cotton production in several ways. In the first place it destroys a certain number of bolls or portions of bolls, in which case the lint produced is short and kinky (fig. 1). The injury, however, does not end with the reduction in the yield of lint. The crop of seed is correspondingly reduced, and what is obtained is of light weight and poor grade. In the crushing of Egyptian seed in England it was found that the oil content was lower than normal by about 20 per cent, and that the oil actually secured was of dark color and comparatively low value. The work of the insect is also of importance in connection with seed for plant-

ing. The percentage of germination is naturally low and much larger quantities must be planted to secure a stand.

It is evident from what has been said that the pink bollworm must be of interest to all classes of persons concerned in the cotton trade as well as to those engaged more especially in the cultivation of the crop and the utilization of the seed.

The most accurate information concerning the damage by the pink bollworm is in a recent paper by L. H. Gough (7). This investigator conducted studies in lower and middle Egypt to determine the number of bolls attacked by the pink bollworm. The samples consisted each of 100 green bolls taken at random in fields in various localities. These samples were sent to Cairo where they were given a very careful examination. The total number of bolls examined in

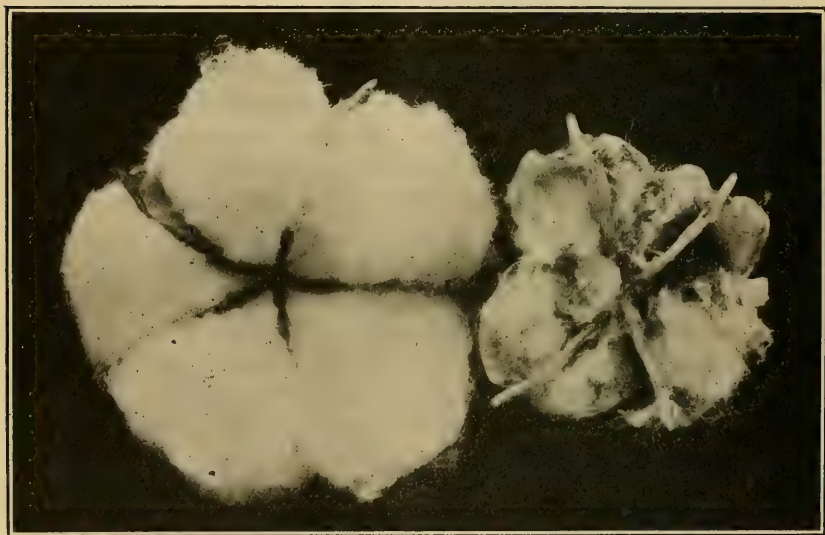


FIG. 1.—At left, normal cotton boll; at right, boll injured by the pink bollworm.

this work was 106,400, and the examinations were continued from July to November. The following are the results of this investigation:

Percentage infested during July, less than 10.

Percentage infested during August, from 10 to 25.

Percentage infested during September, from 25 to 75.

Percentage infested during October, from 75 to 89.

These figures show in a very striking manner the great damage of which the pink bollworm is capable. They may be taken as a fair indication of the injury which would be done in the United States, as the seasonal conditions here are similar to those in Egypt. In short they show that approximately 25 per cent of August bolls and 50 per cent of the September bolls would be destroyed or rendered

practically valueless by the insect. They further illustrate the rapid increase of infestation of green bolls with the advance of the season, and indicate the possibility of a high reduction of yield, particularly in all late-maturing cottons where the second and third pickings are of importance. Fortunately for Egypt, one of the principal varieties of cotton grown there, the Sakellarides, matures its crop early and yields most of its cotton with the first picking. In spite of this favorable condition, however, and of expensive control operations enforced by the Government, a very conservative estimate by experts indicates a loss of at least 17 per cent to the Egyptian crop due to this insect. In the Hawaiian Islands the pink bollworm has prevented the development of the cotton industry which at one time showed considerable promise. With relation to German East Africa a statement is made that the pest normally becomes so abundant in two or three years after its introduction in the field as to necessitate abandoning the crop (11).

In Brazil the Minister of Agriculture recently has collected data for an estimate of the damage to the cotton crop caused by the pink bollworm by addressing communications to the governors of the principal cotton-producing states of the Republic. The following is a summary of the results of this investigation:

Losses on account of ravages of pink bollworm in Brazil: Crop of 1917.

Brazilian state.	American currency.
Maranhac -----	\$ 750,000
Piauhy -----	500,000
Ceara -----	10,000,000
Rio Grande do Norte -----	2,500,000
Parahyba -----	5,925,000
Pernambuco -----	5,750,000
Alagoas -----	1,575,000

The loss referred to in the table ran from 30 per cent of the crop in the State of Alagoas to two-thirds of the crop, or 30,000 metric tons, in the State of Ceara.

In Mexico the actual injury caused by the pink bollworm was investigated by the Joint Commission representing the Mexican and American commissions. This commission visited many plantations in the Laguna in 1917. It reported that the loss to the crop of 1917 chargeable to the pink bollworm was not less than 30 per cent. Mr. August Busck, who was a member of the commission, personally estimated losses ranging from 30 to 50 per cent, with individual fields showing even higher losses.

DESCRIPTION AND LIFE HISTORY.

The pink bollworm has four stages, namely, egg, larva, pupa, and adult or moth. The moth (fig. 2) resembles somewhat the common

clothes moth of this country. From tip to tip of the extended wings it measures from three-fifths to four-fifths of an inch. It is of a dark-brown color, the forewings ending in a rather sharp point. The hindwings are somewhat broader than the forewings and end in an even sharper point. The eggs are very small objects, somewhat oval, about one-twenty-fifth of an inch long and one-fiftieth of an inch broad. The surface is white and finely wrinkled. The larva (fig. 3)



FIG. 2.—The pink bollworm (*Pectinophora gossypiella*): Adult. Much enlarged. (Busck.)

when first hatched is glassy white with light-brown anterior markings. It grows rapidly, and when mature measures nearly a half inch in length. It is cylindrical, white, with the dorsal side strongly colored with pink.

The pupa (fig. 4) is about two-fifths of an inch in length, reddish brown, the posterior end pointed and ending in a hooklike process.

There are several insects found in bolls of cotton in the United States which may be mistaken for the pink bollworm. One of these is the so-called pink cornworm or scavenger bollworm (*Pyroderces rileyi* Walsingham), which frequently is found in decaying bolls, especially those which have been injured by disease. It has not been known to attack healthy bolls. It does not normally make its way into the seed, and this fact will help in distinguishing it from the pink bollworm. Another insect which may be mistaken for the pink bollworm is the common bollworm of cotton (*Chloridea obsoleta* Fabricius). This is the same insect that feeds on corn and is known in some parts of the country as the corn earworm. It bores holes through the carpels of the bolls, feeds for a short time, and then proceeds to another



FIG. 3.—The pink bollworm: Outline drawing of larva, showing structure. Much enlarged. (Busck.)

boll. In the early stages it sometimes assumes a somewhat pinkish color. It may be distinguished from the pink bollworm by its habits, especially by the fact that it does not feed altogether in the interior of the bolls and that it is not found within the seeds. When full grown it is much larger than the pink bollworm, measuring about 2 inches in length.

The insect most likely to be mistaken for the pink bollworm is the boll weevil. Although the boll weevil is sometimes found in seeds, it generally is found feeding within the interior of the boll. It discolors the fiber considerably, and this causes the interior of the boll to assume a more or less decayed appearance, quite unlike the appearance of bolls infested by the pink bollworm, in which decay generally does not occur. *This so-called cleanliness of the work of the pink bollworm is one of the most useful characteristics in differentiation.*

The accompanying illustrations will assist the reader in deciding whether the work in question is that of the pink bollworm or some other insect found in cotton bolls.

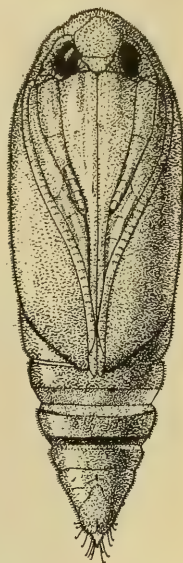


FIG. 4.—The pink bollworm: Pupa. Much enlarged. (Busck.)



FIG. 5.—Exit holes of pink bollworms in cotton bolls.

Figure 5 shows on the left the appearance of the interior of an injured boll, and on the right the characteristic small circular opening made by the larva for the purpose of allowing the adult to emerge.

Figure 6 shows on the left the characteristic opening made by the ordinary bollworm (*Chloridea obsoleta*). It is of large size and surrounded by a raised margin. The exit holes of the pink bollworm, on the right, are much smaller, more regular, and without raised margins.

Figure 7 shows the appearance of locks of cotton, exhibiting typical injury by the pink bollworm.

Figure 8 shows individual seeds infested by the pink bollworm. In the lower line are the "double seeds." These are frequently



FIG. 6.—Two bolls showing distinction between exit holes of the ordinary bollworm or corn earworm (*Chloridea obsoleta*) and those of the pink bollworm (*Pectinophora gossypiella*). The large hole in the boll to the left was made by the ordinary bollworm and the two small ones in the boll to the right are typical of the pink bollworm.

found as the result of the webbing together of two seeds by larvæ of the later stages in order to obtain more room for pupation.

Figures 9 and 10 illustrate the pink bollworm in a burr and the typical opening made by this insect when it makes its way from one lock to another.

Although these descriptions may help in enabling any one to determine whether the pink bollworm is present in a cotton field, it will always be best to send any specimens to an entomologist without delay for authoritative determination. It is extremely important that any possible infestation by this insect be brought to attention

at the earliest possible date, that prompt eradivative measures may be taken.



FIG. 7.—Cotton locks showing typical injury by the pink bollworm (*Pectinophora gossypiella*).

Under the authority of the Federal Horticultural Board, Mr. August Busck spent a number of months in the Hawaiian Islands in 1905 studying the life history and habits of the pink bollworm. His

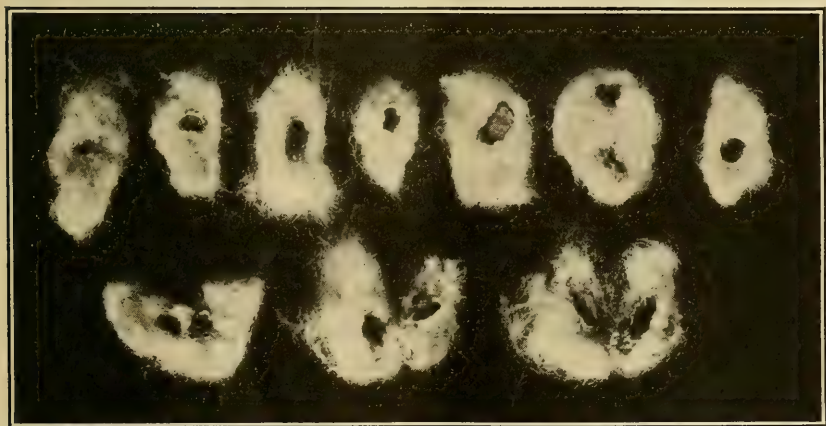


FIG. 8.—Cotton seed containing pink bollworms, opened to show the cells. Both the single and double seeded cells are shown, the double-seeded ones being broken apart.

paper (2) on the subject is by far the most complete of any which has been published. The following statements regarding the life history and habits of the pest are based upon Mr. Busck's paper:

The eggs are laid singly or in small groups on the green bolls or in the flowers. Generally the eggs are to be found near the points of the green bolls in the sutures marking the locks. As many as 4 eggs may be found in this situation and altogether as many as 20 eggs have been found on a single boll. It is estimated that a female will deposit in the neighborhood of 100 eggs. These hatch in from 4 to 12 days.

The larva, immediately on hatching, bores its way into the boll. The infested bolls sometimes become recognizable by a reddish or blackened discoloration which follows attack. Mr. Busck finds, however, that the only conclusive exterior evidence of infestation is the eggshell at the entrance hole or the larva itself within the boll.



FIG. 9.—Pink bollworm on carpel of cotton boll, which shows also typical hole made by worm while traveling from one lock to the next.

The food of the larva is the seed within the boll. It devours one and generally proceeds to the next above. Ordinarily a single larva does not make its way outside of the lock which it first invades, but occasionally the adjoining lock may be entered. It is to be noted that the larva restricts itself to the interior of the boll and never makes its way to the outside for the purpose of reaching another boll. When the larva reaches full growth it often protects itself by webbing two seeds together, the attachment being made to openings brought into contact by

the insect. These "double seeds" are characteristic of the work of the insect. Usually they are not destroyed in the process of ginning, and they furnish the best means of determining quickly whether any lot of seeds is infested.

During the summer the larva stage occupies from 20 to 30 days. Later in the season this stage may be more or less indefinitely prolonged. Gough (6), in Egypt, found that larvæ would remain in a quiescent condition for over two years. Mr. Busck caused infested seeds to be placed in small bales of cotton in Honolulu. Examinations made up to 18 months after the time of baling continued to reveal the presence of live larvæ. It is thus evident that the larva stage may be prolonged over at least two growing seasons. It is this feature in the life history of the pest which has facilitated its carriage to many remote quarters of the earth.

After a variable time, as has been indicated, the larva transforms into a pupa or chrysalis. This stage lasts from 10 to 20 days and then the moth emerges. The life of the moth is rather short. Under favorable conditions Mr. Busck succeeded in keeping some specimens alive for 32 days, but under the same conditions the great majority of the insects died in from 14 to 20 days.

The moth is seldom seen in nature. Its habit is to hide during the day under stones or brush. The normal time of flight is from 6.30 to 8 p. m.¹ Although apparently capable of prolonged flight, they prefer to go no farther than the first cotton field. The moth is so quiet in its habits and so easily overlooked that many may occur

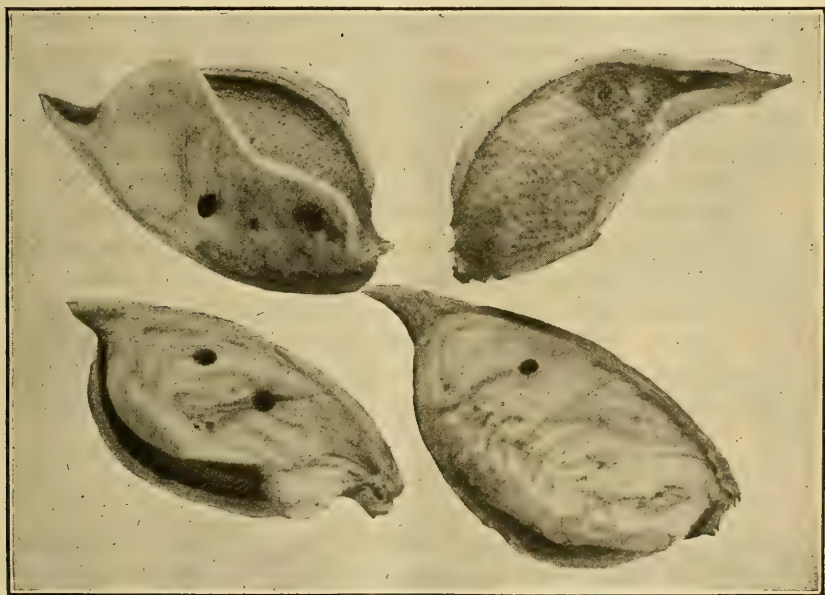


FIG. 10.—Typical holes made by pink bollworms through cotton-boll carpels.

unnoticed in the field. In fact Mr. Busck states that frequently he walked through cotton fields in the Hawaiian Islands where the moths had been emerging daily for an indefinite time, and where many thousands must have been present, without seeing a single one.

Statements to the effect that the pink bollworm is attracted to lights have appeared in the literature. Mr. Busck paid particular attention to this point and demonstrated that in Hawaii lights have no attraction whatever for the insect. In fact, the moths were clearly repelled by light. In Egypt experiments have shown some degree of attraction to light but not enough to form the basis for control measures.

¹ Standard time.

The question of the food plants of the pink bollworm is one which has been discussed at considerable length. There are statements in the literature to the effect that the species feeds on pomegranates in Egypt, on milo in Hawaii, and in Egypt and India on teal, okra, and hollyhock. The record relating to pomegranates has been withdrawn by Mr. H. A. Ballou, who has recently published a statement to the effect that it was an error. With reference to milo Dr. D. T. Fullaway has made a statement that the record was from a single specimen from a fallen fruit and that this specimen may well have been a stray larva which crawled into a cracked milo fruit for pupation.

Mr. Busck's observations in the Hawaiian Islands did not reveal any food plants other than species of the genus *Gossypium*, that is cottons. More recently, however, a statement has been published to the effect that the insect has been reared from a closely related plant belonging to the genus *Hibiscadelphus*.

The subject of the food plants of the pink bollworm in Mexico and Texas is now receiving very special attention. The extent to which okra, hollyhocks, and various wild malvaceous plants will have to be considered as host plants for the insect in noncotton zones depends upon these investigations, which are being prosecuted thoroughly and with the utmost possible dispatch.

As far as observed, the insect has no preference for cultivated varieties of cotton. The perennial or Caravonica, Chinese, Sea Island, and American Upland varieties growing in Hawaii were attacked to the same extent. Similar observations have been made in Egypt and India.

NATURAL ENEMIES.

The pink bollworm has a number of insect enemies wherever it occurs. In the Hawaiian Islands Busck found at least six species attacking it. Other species have been recorded from Egypt, Brazil, and India.

By far the most important enemy of the pink bollworm is a small mite known as *Pediculoides ventricosus* Newport. This is a common enemy of insects and occurs throughout the world. It seems to have increased to a very considerable extent in Egypt, but it does not appear that it is likely to be sufficiently abundant at any time to serve as an important agency in controlling the pink bollworm. Neither does it appear from the available records that any insect or mite enemies of the pest are likely to be of any practical importance in controlling it.

It is interesting to note that the mite to which reference has been made also attacks human beings. In 1914 large quantities of

Egyptian cotton seed were shipped to London. The laborers employed in handling this seed became affected by a rash of the skin caused by the punctures of the mite. The irritation was severe and resulted in a strike for higher wages. Recently the writer has learned from Mr. E. C. Green that in Brazil, since the establishment of the pink bollworm there, children who play about seed houses soon become affected by a dermatitis which probably is the same as that which has been found to follow the attack of the mite in other parts of the world.

PRECAUTIONS TAKEN TO PREVENT THE INTRODUCTION OF THE PINK BOLLWORM INTO THE UNITED STATES.

Prior to 1913 a considerable number of planters and others interested in the production of long-staple cottons in the United States caused small importations of Egyptian seed to be made. They were planted in many of the southern States, but did not result, for various reasons, in the establishment of the culture of Egyptian cottons. The Department of Agriculture also made special importations. In 1902 a considerable quantity of seed was brought from Egypt and small experimental plantings were made at Pierce and San Antonio, Tex., and at various other points in the Southwest. That the establishment of the pest did not follow any of these importations is due to the recent introduction of the insect into Egypt.

With the approval of the plant quarantine act on August 20, 1912, the Department of Agriculture for the first time obtained authority to regulate the importations of plants and plant products from foreign countries and to take the steps necessary to prevent the introduction of injurious insects and plant diseases by such importations. The pink bollworm was one of the first insects to be considered after the plant quarantine act went into operation. Its foreign status and its menace to American cotton was first brought to the attention of the Federal Horticultural Board in April, 1913, and on May 20 of that year a formal hearing was called at Washington to consider the advisability of prohibiting the importation of cotton seed from all foreign countries. No special opposition was encountered and a quarantine was promulgated on May 28, 1913, to take effect on July 1 of that year. This quarantine forbade the importation into the United States of cotton seed of all species and varieties, and cottonseed hulls from any foreign locality and country excepting the Imperial Valley in the State of Lower California in Mexico. The importation from this region in Mexico was covered by regulations. The importance of this action was shown in May, 1913, by the receipt in Arizona of a shipment of 500 pounds of Egyptian seed

which was found to have an infestation by the pink bollworm of about 20 per cent. Thanks to the quarantine law in Arizona and the activity of Dr. A. W. Morrill, the State entomologist, the whole shipment was destroyed by fire.

A little later (Aug. 18, 1913), on the recommendation of the experts of the Bureaus of Entomology and Plant Industry of this department, this quarantine was amended in such manner as to provide, under regulation, for the entry, for milling only, of cotton seed from the States of Nuevo Leon and Tamaulipas, Mexico. A still later amendment permitted the introduction of seed from other of the northern states of Mexico.

The reasons advanced for allowing such entry of Mexican cotton seed were that no insects which were not found in the United States were known to occur there, and that the culture of cotton is more or less continuous with that in the United States. The absence of any cotton pests in the Republic of Mexico which did not occur in the United States at that time had been established by field inspections by several of the entomologists of the department.

To protect the United States from the possible entry of the pink bollworm from the Territory of Hawaii, a domestic quarantine was promulgated June 24, 1913, prohibiting the importation of cotton seed and cottonseed hulls from this territory.

It was thought that the United States was sufficiently safeguarded against the pink bollworm by the quarantines against cotton seed as such, but it soon came to notice that considerable quantities of seed were coming to the United States in bales of lint. A careful examination of picker waste from a large number of bales of Egyptian cotton was made. It was found that considerable numbers of seeds passed around the rollers in the gins and some between the roller and the knife through small openings due to wear. The waste from 37 bales which was examined showed sound seeds, some of them infested, varying from 27 to 600 per bale. The average per bale was 215. The variation in the different bales depended upon the grade of the cotton, the lower grades having many more seeds than the better ones. It was estimated on the basis of the examination of waste from the 37 bales that over 16,000 live larvæ of the pink bollworm were being brought to the United States each year, of which several hundred went to the mills in the cotton belt.

It thus became evident that a quarantine which did not take into consideration the seeds in bales of lint was inadequate. Consequently in May, 1914, a public hearing was held to discuss various means of protection. The different proposals made were that foreign cotton be excluded altogether from the United States; that it be admitted only under a guaranty that all seeds had been eliminated, or

that it had been disinfected; that it be allowed to proceed only to mills outside of the cotton belt; and that it be sent to southern cotton mills only after a period of storage of 18 months or more in northern localities. At the public hearing, and subsequently through conferences with members of the cotton trade and representatives of manufacturing associations whose assistance was very valuable to the department, it became evident that there were insuperable obstacles in the way of any of the plans mentioned. It therefore became necessary to make an exhaustive study of the possibility of destroying any infestation which might be found in the bales of lint. The use of cold was found to be impracticable. The use of heat was also impracticable on account of the time necessary to penetrate the highly compressed bales of Egyptian cotton and on account of the increased danger from fires when bales which had been heated were opened in the mills.

About this time Mr. E. R. Sasscer, of the Federal Horticultural Board, and Dr. Lon A. Hawkins, of the Bureau of Plant Industry, had been conducting some experiments in the destruction of insects in various plant products by fumigation in a vacuum. It was found that the killing power of hydrocyanic-acid gas was increased enormously in vacuum and it thus became possible to reach certain classes of insects which heretofore had been uncontrollable. It therefore seemed possible that the vacuum process might be utilized in the fumigation of bales of cotton without necessitating their opening. A small experimental plant was established by the board at Washington and a long and what turned out to be a most interesting series of experiments was begun by Mr. Sasscer.

While this investigation was in progress an order regulating the entry of all imported lint cotton was promulgated by the Secretary of Agriculture April 27, 1915, effective July 1, 1915, and a domestic quarantine regulating the movement of cotton lint from the Territory of Hawaii to the mainland was promulgated June 11, 1915, effective on and after July 1, 1915. Under this order and quarantine, tentative regulations were issued governing and restricting the entry of foreign cotton and also providing for the screening of all rooms or buildings in which foreign cotton was kept and the daily burning of all grades of mill waste in which seeds of such cotton might be found. A corps of inspectors was employed and frequent examinations were made at the mills where foreign cotton was used to insure the faithful following of regulations. In general sympathetic cooperation was obtained. This was especially noticeable in the case of southern mills, the owners and managers of which seemed to realize the danger of introducing the pink boll-

worm and complied with the orders and regulations of the Federal Horticultural Board in the most hearty and public-spirited manner.

In the experiments with vacuum fumigation of lint cotton conducted by Mr. Sasscer, under the direction and with the advice of the Federal Horticultural Board, tests were made with variations in the dosage of cyanid, the degree of vacuum, the length of exposure, the temperature, and also in the depth of penetration. Steel tubes pointed at one end were provided. These had perforations near the point and were sealed in such a manner as to be perfectly airtight at the other end. Insects were placed within them, and the tubes were then driven into the bales. After the experiment was performed the insects were removed for examination. In this way the exact effect of the fumigation under all varying conditions at different depths within the bales could be determined. At the same time chemical tests were made by the Bureau of Chemistry of this department to run parallel with the tests with insects. These chemical tests confirmed the rapid penetration of the gas.

As the result of a suggestion made following a conference of a committee of cotton manufacturers with the Federal Horticultural Board, the then Office of Markets and Rural Organization of this department conducted a series of manufacturing tests with cotton which had been fumigated with hydrocyanic-acid gas to determine whether the fumigation by this agent would cause any injury to cotton fibers. The results of these tests indicate that such fumigation of cotton did not cause any deterioration of the cotton, either as to percentage of waste, spinning qualities, tensile strength, or bleaching, dyeing, or mercerizing properties of the cotton (3).

In the first series of experiments various insects more or less related to the pink bollworm, but which are native to the United States, were used. After the preliminary work was done and the probable requirements for destroying any insect in the bales of lint were determined, it was decided to add a series of experiments with the pink bollworm itself. For this purpose, under extreme caution to avoid escape, a number of insects were brought from the Hawaiian Islands. The results in all essential respects were similar to those that followed in the case of the insects treated previously.

As the result of all of this work, which taxed the ingenuity of the investigators engaged in it, it was found feasible on a commercial scale to fumigate densely compressed bales of cotton and kill any insect which might be inside.

On March 10, 1916, the fumigation of all bales of foreign cotton arriving at the United States was required as a condition of entry. Advance notice had been given to the importers and others concerned. In spite of considerable difficulties in obtaining materials and in working out mechanical problems, large plants were erected

in a remarkably short time and became available for use on the date mentioned. Two of these plants were erected in Boston and one at Oakland, Cal. A little later additional plants were erected at New York City and Newark, N. J., and two plants are now available in Seattle, Wash. These establishments have a capacity sufficient to handle all of the imported cotton without any special delay. The larger plants have a capacity of upward of 1,000 bales per day.

The procedure to be followed in the fumigation of foreign cotton is given in an order of the Federal Horticultural Board (12). The kind of cyanid and sulphuric acid is specified. The rate is 6 ounces of sodium cyanid per 100 cubic feet. The cotton to be fumigated is placed in the fumigating chambers, the doors to these chambers are closed, and the air is exhausted until the vacuum gauge registers 25 inches. At this stage the gas is generated in a retort connected with the large chamber. The valve of the connecting pipe is opened; after the expiration of 15 minutes air is allowed to pass through the generator for 5 minutes for the purpose of removing any gas which may be present. The air valve on the fumigating chamber is then opened and the air allowed to rush in until the gauge registers 5 inches. The cotton then remains in the chamber for 1 hour and 40 minutes, making the total process of fumigation 2 hours. After the completion of the exposure, to remove the gas the pumps are run again and a vacuum of 25 inches established. At this stage the valves are opened and the pumps kept running for some time to complete the washing out of the gas from the bales. The pumps are then stopped and the doors of the chamber opened so that the cotton can be removed and another lot put in.

On December 27, 1915, Mr. R. I. Smith, the inspector of the board at Boston, Mass., called the attention of the board to the fact that a considerable amount of cotton waste was being imported. Some of this waste was found to contain more than twenty times as much seed as a bale of ordinary cotton. On this account the definition of the term "cotton" in the regulations was changed to include all grades of cotton waste except those resulting from processes of manufacture which render it mechanically impossible that seeds may be contained. These are the grades of waste resulting from the carding machines and subsequent processes in the manufacture of cotton. The requirement of fumigation of cotton waste went into effect on February 16, 1916.

On April 11, 1916, the collector of customs at Norfolk, Va., telegraphed the board that some 189 tons of cotton seed from Lagos, West Africa, constituted a portion of the cargo of the British steamship *Appam*, brought to Newport News as a German prize of war. In cooperation with the Office of Markets the board took immediate steps

to dispose of this seed, which was found to be infested by the pink bollworm. A provisional sale had been made by the admiralty board to the proprietor of an oil mill in South Carolina. This was set aside as soon as the danger of introducing the pink bollworm was explained. After considering a number of methods of disposing of this seed, it was finally decided to have it treated with sulphuric acid and thus made available as a fertilizer. Through the cooperation of one of the largest manufacturers of fertilizers this was done with the utmost dispatch. The entire lot of 4,000 bags of seed was placed in sulphuric-acid vats within four days from the time the presence of the seed at Newport News became known to the department. As an additional precaution the two holds of the *Appam* which contained the seed were fumigated with a heavy dose of cyanid, and the docks, lighters, and trucks, as well as floors and platforms, were thoroughly cleaned of any scattered seeds.

To guard against the possibility that the pink bollworm had escaped prior to the treatment which has been described, repeated inspections were later made of the cotton fields near Newport News, which are at a distance of about 10 miles. No traces of infestation have been found, and it now seems certain that the establishment of the insect from this seed was prevented.

The chief inspector of the Board in New York City, Mr. Harry B. Shaw, reported in February, 1916, that there appeared to be considerable risk of introduction of the pink bollworm or other cotton insects with old burlaps which had been used for coverings of cotton and to which, as a rule, considerable cotton and occasional cotton seeds remain attached. Such burlaps are imported in large quantities for paper manufacture and other uses, and an investigation which was made of such imports in New York and Boston fully confirmed the risk of the introduction of cotton and cotton seed with such materials. An amendment was therefore added to the rules and regulations governing the importation of cotton into the United States, effective August 1, 1916, providing for the inspection and, where necessary, disinfection of all burlaps or other fabrics offered for import which had been used for covering cotton and to which cotton was adhering.

The possibility of entry of uncrushed seeds containing living pink bollworms or other cotton insects with cottonseed products, such as cake and meal, became evident after careful examination of such imports, and to safeguard their entry an order restricting the admission of cottonseed cake, meal, and all other cottonseed products, except oil, from all foreign countries was promulgated June 23, 1917, and regulations under this order were issued June 29, 1917, effective on and after July 16, 1917.

DISCOVERY IN MEXICO.

Earlier in this bulletin attention has been directed to the fact that when the quarantine against foreign cotton seed was placed in operation the State of Lower California, Mexico, was not included, and that subsequently cotton seed was permitted entry, for milling purposes only, from certain northern States of Mexico. The reason for this was that several of the entomologists of the department had been in northern Mexico and had found no traces of infestation by any insects other than those which are known to occur in the United States. These explorations were made some years ago, however, and it was still thought desirable to have new examinations made on account of the suspicion that the pink bollworm or some other destructive pest might have been introduced in the meantime. Accordingly arrangements were made in 1916 to dispatch an agent to Mexico. Shortly before the time fixed for his departure the activities of the bandits became so great that the trip had to be postponed indefinitely. If it had not been for these circumstances the presence of the pink bollworm in Mexico would have been known some months before it actually came to the attention of the department.

On November 1, 1916, the department received from a planter in the Laguna, who was then residing in Mexico City, a number of specimens of cotton bolls which had been attacked by insects. The sender was under the impression that the insect was the boll weevil which, though introduced in the Laguna on numerous occasions, had never been able to maintain itself on account of climatic conditions. Several of the bolls were found to be infested by the boll weevil, but others showed the presence of the pink bollworm. The determination was first made by Dr. W. D. Pierce and confirmed by Mr. August Busck and other specialists of the Bureau of Entomology.

On November 3, 1916, the situation was considered by the Federal Horticultural Board, and on November 4 an amendment to the regulations extending the quarantine to cotton seed and cotton from Mexico was issued by the department. An investigation was immediately started to determine the extent of the infestation in Mexico and the number of shipments of cotton seed from that country to the United States. It was soon found that a large amount of Mexican cotton seed had been shipped to mills in Texas during the season of 1916. In previous years no Mexican cotton seed had been shipped to the United States, and it was only the disturbed conditions in Mexico and the unprecedented high price of seed in the United States which caused the seed mentioned to be forwarded to the United States.

It was found that a total of 446 carloads of Mexican seed had entered the United States during 1916 prior to November 4. These car-

loads went to mills at Beaumont, Pearsall, Kaufman, Hearne, San Antonio, Houston, Dallas, Wolfe City, New Braunfels, Grand View, and Alice. The amounts varied from one carload, which went to Wolfe City, to 114 carloads, which went to Beaumont. Ninety-three carloads were shipped to Hearne and 69 to Kaufman, both located in regions where cotton is cultivated on every plantation.

The State authorities in Texas were notified and the Federal Horticultural Board began a campaign to expedite the crushing of the seed and the destruction of any scattered seeds about the premises. The cooperation with the State was through Hon. Fred. Davis, commissioner of agriculture, the entomologist of his department, Mr. E. E. Scholl, and the chief nursery inspector, Mr. E. L. Ayers.

Agents of the Federal department visited the mills which had received the Mexican seed at frequent intervals through the fall and winter. The force was increased by the addition of three men detailed from the Office of Markets of this department. The proprietors of the mills and the State Cottonseed Crushers' Association all assisted very materially in the work, which was done with the utmost possible dispatch and with great thoroughness.

SPECIAL APPROPRIATION FOR THE DEPARTMENT OF AGRICULTURE.

In November, 1916, the department submitted to Congress an estimate for an appropriation of \$50,000 to be used, first, in determining the possible presence of the pink bollworm in the vicinity of the mills which received Mexican seed and to stamp out any infestation which might be found; second, to enforce the quarantine against Mexican seed and cotton products which might carry the pink bollworm. This appropriation became available on March 4, 1917.

Under the appropriation the Federal Horticultural Board organized a full field force. It consisted of one set of inspectors to make field examinations to determine whether the pink bollworm could be found, and another to enforce the quarantine regulations at the border ports.

DISCOVERY IN TEXAS.

As the result of the field examinations, to which reference has been made, the first specimen of the pink bollworm in Texas was discovered in Hearne, Tex., on September 10, 1917, by Ivan Schiller, an inspector of the board. This was found in a small field adjoining the oil mill which had received Mexican cotton seed. Later four additional specimens were found, none of them more than one-fourth of a mile from the mill. On October 5 a specimen was found in a field near the oil mill at Beaumont by inspector H. C. Millender, and on October 25 specimens were taken at Anahuac, in Chambers County, by Mr. H. S. Hensley. The first two of these infestations

were undoubtedly due to the Mexican seed which had been shipped to the United States in 1916. The infestation in Chambers County, however, can not be attributed to such shipments. It was found to extend around Galveston Bay from Smiths Point to the vicinity of Texas City. It was heavier near the Bay and diminished regularly toward the interior. After considerable investigation, in which all possible theories have been investigated, the conclusion has been reached that this infestation was probably due to Mexican bales of cotton which were shipped to Galveston in 1915. During this year several thousand bales of cotton from the Laguna in Mexico reached Galveston by way of El Paso. This cotton was on the docks at Galveston at the time of the hurricane of August, 1915. With several thousand bales of Texas cotton it was washed from the docks and distributed around the shore line, in some cases 75 miles away. Many of these bales were broken open by the force of the water. It is well known that Mexican bales contain large numbers of seeds, and cotton plants were found growing along the high water line during the fall of 1915 and the spring of 1916. This theory, while not altogether satisfactory, is considered by Mr. August Busck, who has paid more attention to the study of the pink bollworm than any other entomologist, to be adequate to explain the known situation at the present time around Galveston Bay.

As soon as the presence of the pink bollworm in Texas was discovered the Federal Horticultural Board, in cooperation with the Department of Agriculture of the State of Texas, undertook active measures to eradicate it. The work consisted at first of scouting to determine the limits of infestation, the destruction of any possible infestation remaining in the fields, and the safeguarding by various means of the cotton produced in the infested fields and in neighboring ones during the season of 1917.

Entomologists were obtained from various sources. Twenty-five were engaged in the scouting work in Hearne, and later about 50 in the work in southeastern Texas. As the result of this work it seems practically certain that the infestation in Hearne was limited to the immediate vicinity of the oil mill. In southeastern Texas infestation was found from the vicinity of Beaumont, in Jefferson County, to Arcola, about 7 miles from the Brazos River. The northernmost point infested was in Liberty County, about 18 miles north of the town of Liberty. This area includes all of Chambers, Galveston, and Jefferson Counties, and portions of Liberty, Harris, Brazoria, and Hardin Counties.

The work of removing any possible infestation from the fields consisted of uprooting or chopping down the plants, the collection by hand of all locks or portions of locks which were found on the ground, and the burning of all the accumulated trash with the use

of kerosene. In this work 1,624 acres of land in the vicinity of Hearne were cleaned, and 7,170 acres in southeastern Texas. The work was not confined to fields in which infestation was actually found, but included fields at a considerable distance beyond the outermost points found infested. It involved the employment of an average of about 500 laborers for the months of November, December, January, and February, and a portion of March. In many cases the laborers were assembled in camps and housed and provisioned by the department. In other cases, where the work was in the vicinity of towns, it was possible to employ local labor. The safeguarding of cotton products produced in the infested areas in 1917 consisted of the milling of the seed under supervision at certain mills selected because their construction would enable the work to be done with practically no danger of disseminating the pest. The baled cotton, so far as possible, was caused to be exported or shipped directly to northern mills.

COTTON-FREE ZONES.

In 1917 the Legislature of Texas passed an act intended to give authority to prevent the establishment of the pink bollworm in the State. Under this act authority was granted to quarantine the districts in which the insect might be found, and to establish zones in which the planting of cotton might be prohibited. Under this authority on January 21, 1918, the governor of Texas quarantined the Hearne district as well as the territory found infested in southeastern Texas. In the case of Hearne the quarantined area included a territory within a radius of 3 miles from the mill. In the case of southeastern Texas the quarantined area included a safety zone on the outermost points infested approximately 10 miles in width.

On February 25, 1918, following the recommendation of Hon. Fred W. Davis, commissioner of agriculture, the governor of Texas issued a proclamation prohibiting the planting of cotton in the quarantined areas.

The finding of infestation by the pink bollworm in Mexico not far from Del Rio in the spring of 1918 made it necessary to place in operation another section of the Texas pink bollworm act. As a consequence a third noncotton zone was provided to include McKinney, Maverick, and Valverde Counties.

SPECIAL REGULATION AT MEXICAN BORDER.

The risk of direct entry of the pink bollworm from Mexico by flight or by accidental carriage necessitated the provision in the regulations governing the entry from Mexico of cottonseed cake, meal, or other cottonseed products, including oil, that permits for such entry should be issued only for the products named produced in

mills located in the Laguna district of Mexico. The object of this proviso with relation to Mexico is to deter the erection of mills near the border of the United States with the consequent risk of escape of insects from seed brought for crushing to such mills near the border.

In this connection it may be noted that active steps toward the control of the pink bollworm have been undertaken in Mexico. A recommendation was made to the Mexican Government by a joint commission, one of the members of which is Mr. August Busck, of the United States Department of Agriculture, that the cultivation of cotton in infested regions be prohibited for a period of three years. It has not been possible up to the present time for the Mexican Government to place this recommendation in operation, but it has issued two decrees looking toward the control of the insect. One of these is a quarantine against the main infested territory with a provision for a safety zone of considerable width. The other provides for the fumigation of all cottonseed produced, whether intended for crushing or planting.

PRESENT WORK OF THE DEPARTMENT OF AGRICULTURE.

To meet the menace of the pink bollworm the activities of the department through the Federal Horticultural Board now include:

(1) The exclusion from the United States of cotton seed from all foreign countries except the Imperial Valley of Lower California, Mexico, and its exclusion also from Hawaii;

(2) Regulating and safeguarding the entry of cottonseed products from all foreign countries and from Hawaii;

(3) Regulation of entry and disinfection of all imported cotton and cotton waste, and also burlaps which have been used as wrappings of foreign cotton, including such material from Hawaii;

(4) Survey, eradication, and control work in Texas in cooperation with the State authorities;

(5) Regulation of rail and other traffic with Mexico;

(6) Determination of distribution in Mexico and cooperation in control measures with the Mexican Government or local Mexican authorities; and

(7) Investigation in Mexico of the life history and habits of the pink bollworm as a basis for control measures.

Detailed information as to these activities and the quarantine and other restricting orders and regulations in relation to cotton and cotton products are given in the monthly numbers of the Service and Regulatory Announcements of the Federal Horticultural Board (13).

In general the work in Texas consists of cooperation with the State of Texas in maintaining the cotton-free zones and safeguard-

ing the products produced therein in 1917, in extensive scouting to determine at the earliest moment the occurrence of the insect in any point in Texas or elsewhere, and in eradivative work.

The work at the Texas border ports consists of the regulation of the traffic from Mexico to prevent the importation, through accident or otherwise, of any Mexican cotton seed. It includes the inspection and disinfection of baggage, the cleaning or disinfection of all freight, express, and other shipments, except those which could not possibly carry infestation, restrictions on the entry of railway cars from Mexico, regulation of the transfer of freight, express, and other shipments, certification of all cars or other carriers of merchandise as a condition of entry into the United States (excepting merchandise or other materials of strictly local origin), and the cleaning of domestic cars as a condition of receiving freight originating in Mexico for movement into the interior of the United States.

The work in Mexico consists of cooperation with the Mexican Government and the planters to stamp out the pink bollworm in that country. The main infestation in the Laguna offers a hopeful opportunity for eradication on account of the loss which the pink bollworm has already shown itself capable of causing, and the fact that the cotton lands are owned by comparatively few persons. The other two infestations in Mexico are on individual ranches where it may be possible to have the planting of cotton abandoned for a series of years beginning with 1919. The work in Mexico also includes an investigation of the life history and habits of the pink bollworm with special reference to means of control.

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DRAINAGE METHODS AND FOUNDATIONS FOR
COUNTY ROADS.

By E. W. JAMES, *General Inspector*, VERNON M. PEIRCE, *Assistant Engineer*, and
CHARLES H. MOOREFIELD, *Senior Highway Engineer*.

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The first essential feature of an improved road is adequate drainage. It is practically impossible to secure satisfactory results unless this feature be given proper attention. Another prime requirement, wherever a hard-surfaced road is to be constructed, is that a firm and unyielding foundation be provided. The purpose of this bulletin is to supply information concerning the proper methods of draining roadbeds, constructed of various kinds of soil, under different topographic conditions, and also to explain how foundations may be designed to suit the soil conditions, the road surface, and the system of drainage. Since the quality of the soil has such an important influence both on the proper method of drainage and on the proper type of foundation to be employed, it is desirable first to discuss briefly some of the most important characteristics of the different kinds of soils ordinarily encountered in highway construction.

PRIMARY SOILS.

The texture and structure are the principal properties of soils that determine the manner in which they should be drained and prepared for road foundations. These are important because of their effect on the permeability and capillarity of soils. For the purpose of this discussion, primary soils may be classified as gravel, sand, and clay; but it should be borne in mind that many of the secondary or mixed soils, because of their more general occurrence in connection with road-building connections, are equally important with these. This is especially true of some of the more clearly defined derivative or secondary soils such as loam, marl, gumbo, hardpan, etc. Where a soil is composed of two different materials, mixed in such proportions that its character is decidedly intermediate, it may be designated

conveniently by naming both materials, as sand-clay, sand-gumbo, gravelly-clay, etc.

Clay.—Clay is a soil of very fine texture which results from the complete disintegration of rocks or minerals. Pure clay is very retentive of water and becomes plastic and unstable when wet. It is very difficult to drain, and, on that account, when it occurs in the subgrade of a road, the system of drainage should be designed with a view to preventing water from reaching the subgrade rather than to draining water from the clay. Most clays as they occur in nature contain more or less sand or gravel, which has a stabilizing effect by making the clay more easily drained and by furnishing a combination of mechanically interlocking grains. A mixture containing about 50 per cent each of clay and gravel or coarse sand often makes an excellent soil of which to construct roadbeds. Such a soil, in addition to being easily drained, has less "capillarity" than clay, and consequently does not need to be drained to so great a depth in order to prevent water from rising to the surface. Furthermore, it is moderately stable, even when wet.

Sand.—Sand is made up of granular particles of mineral or stone which occur in nature and which will pass a $\frac{1}{4}$ -inch mesh screen. Particles which are too large to pass such a screen are called gravel. Nearly all natural sand consists of particles which are composed principally of quartz, individually very hard and durable. There is no coherence between the different grains, however, and soils composed principally of sand are unstable, unless properly confined and protected from undermining, in which case a good quality of sand may make an excellent subgrade for some types of road crusts and for practically any kind of foundation. Sandy soils usually require very little drainage except when the sand is mixed with a considerable percentage of fine silt. Sand so fine and evenly graded that it becomes saturated readily with water and remains so for more or less lengthy periods is called quicksand and has little dependable stability.

Loam.—A mixture of soil composed of clay or sand and a considerable percentage of decayed vegetable matter is called loam. All such soils usually contain both clay and sand in greater or less amount, and the quality of the loam for road-building purposes is largely dependent on the proportion in which the sand and clay are present. Most loams are drained comparatively easily, but are subject to the disadvantage that the vegetable matter they contain may be incompletely decomposed and subsequent decomposition eventually may cause more or less settlement and shrinkage.

Gravel.—Gravel is made up of small angular or rounded particles of stone which occur in nature and which are sufficiently large to be retained on a $\frac{1}{4}$ -inch mesh screen. Gravelly soils are distributed widely in the United States and vary greatly in quality. In general,

when a soil contains as much as 40 or 50 per cent of gravel and sufficient clay or other bonding material to hold the particles of stone together it proves very satisfactory as a material for a roadbed, because it is drained easily and is very stable when compacted.

Marl.—Marl is a clay containing a large percentage of carbonate of lime. Frequently it contains shell fragments and nodules of chalk or silica, and other materials. It grades into calcareous clay on the one hand and into argillaceous limestone on the other, and its quality for road-building purposes varies to a considerable extent. In general this material has few advantages over ordinary clay for use in constructing a roadbed unless the percentage of lime carbonate be sufficiently high to give the material, when compacted, approximately the character of limestone.

Gumbo.—Gumbo is essentially clay or silt containing a high percentage of decayed vegetable matter and a very low percentage of sand. It has a very strong tendency to absorb and hold water, and therefore is hard to drain. If drained properly it may make a fair subgrade on which to place the foundation of a road, but it has comparatively a very low bearing value, and where used as the foundation the design should be such as to give a greater distribution of concentrated loads than is necessary with most other soils.

DRAINAGE.

In the design of a road the drainage structures are planned to take care of water under three general conditions: (1) The rain that falls on the road surface or grade, (2) the rain that falls on contiguous land and flows in accumulated volume toward the road, and (3) ground water from any mediate or immediate source. The structures commonly used to provide drainage and meet these conditions are longitudinal side ditches, usually parallel or approximately parallel to the center line; intercepting ditches to accommodate water whose approach so close to the roadway as the side ditches is likely to cause injury; lateral ditches or culverts to conduct accumulated water away from or under the road; and subdrains.

The side ditches are primarily to care for water flowing from the road surface and consequently are placed close to the surface or made a part of it, and their use is so general that it is universal practice to incorporate them into the design of the road cross section. If they actually are made a part of the surface, or an extension of it, they take the form of gutters. As gutters, their effect is not entirely the same as when constructed in the form of a ditch, as in the former case they do nothing toward draining the soil of the roadway, while as ditches they frequently reach such effective depth, as the result of cutting and filling along the grade, that they not only serve to carry away surface water but also do more or less toward lowering the water table under the traveled way.

Intercepting ditches also are usually approximately parallel to the center line but are more remote, often being placed outside of grading lines as berm ditches. Not infrequently intercepting ditches, on account of the immediately local conditions, are constructed so close to the roadway that they can be incorporated into the general cross section, but in such cases their design is independent of the other cross-section details, except as limited by them. Extreme cases of this last condition exist when a road is constructed close to a drainage ditch or irrigation canal, or when, as has occurred not infrequently, the spoil bank of such a canal is used as a road grade. In such cases the side ditch is omitted sometimes on the side toward the intercepting drainage ditch, or a gutter design is used and the flow in the gutter frequently turned into the larger channel. Lateral or cross drains, whether involving the construction of culverts or not, are to divert the flow from any longitudinal drain into a natural drainage channel. If this diversion involves crossing the center line it usually requires a culvert. If it does not cross the center line open lateral ditches are used. Subdrains are used to collect and carry to a suitable outfall water that exists or may accumulate periodically in the soil beneath the road surface or grade. Their use, design, and location depend on the presence of ground water and on the nature of the soil. A retentive impervious stratum underlying a road may prevent the downward percolation of surface water to such an extent as to do injury by saturating the soil, or the presence of springs or other flowing ground water may require their use. In general, subdrains are employed for three purposes appropriate to the conditions existing. They are used to divert springs or confined streams of underground water; to intercept the flow of underground water in the form of general seepage from sources more or less distant; and to lower the water table in places where the nature of the soil causes such water to rise too close to the surface to permit of securing adequate bearing values in the soil.

These various forms of drainage structures may be grouped into two classes according as they provide for surface or subsurface drainage. Obviously, as between the classes, the distinction is reasonably sharp, although, as pointed out, side ditches sometimes serve to lower the water table; but the distinctions between the various uses of the two types with regard to their respective purposes is often, if not generally, impossible of clear definition. This is true especially of subdrains. No matter what condition has led to the design and use of a subdrain, if occasion arises it may act in all of its common capacities.

Further, these types of drainage structures must be grouped and interrelated so as to produce the effect desired under the existing conditions. The drainage problem, especially as affecting foundations, is essentially a local one. This is apparent in some of the

older States where the system of State roads has changes in the foundation design at frequent intervals; and is, of course, doubly apparent from the location and relation of the constantly changing units of the surface drainage system.

In order, therefore, to plan intelligently a system of drainage for any particular road, it is necessary to take into consideration not only the local character of the soil composing the roadbed, but also the topography of the adjacent land, the amount and rate of rainfall, and the availability of different materials suitable for use in constructing drains.

Topography has a very important influence in determining the relation of surface and subdrainage, and when one or the other drainage is more practicable. When the topography is such that the side ditches can be given a grade of as much as 1 or 2 per cent, subsurface drains seldom are necessary, except in unusually heavy clay soils and where springs occur; while, on the other hand, where the grade is level or nearly so, subsurface drainage may be required when the soil composing the roadbed otherwise would be comparatively easy to drain.

The topography of the land adjacent to a road determines to a considerable extent also the necessary capacity of the surface drains and the location of the appropriate structures. Watersheds having a fan shape, for example, empty the water which falls upon them into the drainage structures much more rapidly than long, narrow drainage areas, because of the difference in time required for water from the more remote parts of the area to reach the outlet. Steep slopes deliver water at the outlets much more rapidly than flat areas; and impervious soils, by refusing to absorb precipitation, deliver greater percentage of rainfall at the outlet.

The amount and rate of rainfall are the primary factors in determining the quantity of water drained off from the land, or "run-off," as it is called. Since the capacity necessary for a given drain is fixed by the maximum run-off which it will be called upon to accommodate, a knowledge of the rainfall is essential in planning a system of surface drainage. In the design of surface drains and culverts it is usually necessary to consider only the maximum rate of rainfall and the maximum duration of time through which individual rains continue, but in the case of subsurface drains the duration of a wet season and its effect on the accumulation of ground water also may be of importance. During the most extreme local storms occurring in some sections of the United States the precipitation sometimes amounts to 7 or 8 inches in 24 hours, and in a few cases has been known to exceed an inch in one hour. Where the topographic conditions are favorable to a rapid run-off, such as is generally the case with an improved road, from 80 to practically

100 per cent of the total precipitation may be drained from the watershed during a storm. The extreme rate occurs principally in paved cities in the closely built up business sections, but 80 per cent run-off may occur in very steep, impervious or compactly shaped watersheds. Under the worst conditions, therefore, it may be necessary to design surface drains and culverts with capacity sufficient to remove about 6 inches of water from a watershed in 24 hours and to take care of an extreme precipitation of about 1 inch in 1 hour. Under other circumstances, the maximum rate of rainfall may be considerably less than that mentioned above, and the maximum run-off during storms may be only about 15 or 20 per cent of the total precipitation on the watershed, though this low run-off does not apply often to road drainage.

CAPACITY OF DRAINS.

The amount of water required to cover an acre of land to a depth of 1 inch is 3,630 cubic feet. If the maximum rainfall and run-off and the area to be drained can be determined, therefore, the total volume of water which a given drain should be designed to accommodate can be computed readily. From what has been said, it is apparent that any estimate of the run-off necessarily will be a rather rough approximation, and due allowance on the safe side always should be made as a safeguard against possible inaccuracies in such estimates.

The size of drain necessary to carry a given volume of water in a given time may be estimated from the formula $v=c\sqrt{rs}$, in which v =mean velocity of water; r =hydraulic mean radius of the drain; s =the slope of the drain; and c =a coefficient, the value of which depends on the character of the surface of the drain, the slope, and the hydraulic mean radius. Kutter's formula is the one generally considered most reliable for determining the value of the coefficient, c . According to this formula when English units are used,

$$C = \frac{41.6 + \frac{.00281}{s} + \frac{1.811}{n}}{1 + \frac{\left(41.6 + \frac{.00281}{s}\right)n}{\sqrt{r}}}$$

in which s =slope ratio of drain; r =hydraulic mean radius in feet, and n =a constant which depends on the character of the surface of the drain. Under average conditions the value of n may be assumed as follows: for open ditches, 0.025 to 0.040; for cobble gutters, 0.020 to 0.035; for concrete gutters, 0.015 to 0.020; for tile pipe, 0.015. The following tables have been computed by means of the above formulæ especially for use in planning drainage systems.

VELOCITY-QUANTITY TABLE No. 1.—For earth ditch having cross section shown in figure 1.

Value of "n" ranges from 0.025 to 0.040. Value used in this table is 0.030. W is width of bottom of ditch, in feet. D is depth of water flowing in ditch, in inches. A is area of wetted cross section, in square feet. R is hydraulic radius. C is from Kutter's formula for same. V is velocity in feet, per second. Q is discharge, in thousand cubic feet per hour. Velocities above and to the left of the heavy line are safe for ordinary soils.

Slope, in feet per foot.																										
W	D	A	R	C	0.001		0.003		0.005		0.01		0.02		0.03		0.04		0.05		0.07		0.10			
					V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q		
0.5	2	0.133	0.1132	21.4	0.23	0.110	0.39	0.187	0.51	0.244	1.774	1.32	2.510	1.36	3.549	2.28	4.349	1.44	0.689	1.61	0.770	1.91	0.914	0.228	1.090	
.5	4	.362	.1965	26.6	.37	.482	.64	.834	.84	1.090		1.18	1.538	1.66	2.165	2.04	2.657	2.36	3.076	2.64	3.440	3.12	4.060	3.72	4.850	
.5	6	.688	.273	29.7	.50	1.230	.90	2.220	1.10	2.720		1.50	3.720	2.20	5.450	2.70	6.680	3.10	7.670	3.50	8.670	4.20	10.410	4.90	12.150	
.5	12	2.250	.500	36.5	.80	6.480	1.40	11.340	1.80	14.580	2.40	18.500	2.60	21.050	3.70	29.970	4.50	36.450	5.20	42.120	5.80	46.990	6.80	55.050	8.10	65.600
.5	18	4.690	.716	40.7	1.0	16.890	1.90	32.100	2.40	40.500	3.40	51.400	3.90	82.700	6.00	101.400	6.00	101.400	6.00	116.500	7.70	130.000	9.00	153.580	10.00	168.600
.5	24	8.000	.932	44.1	1.30	37.450	2.30	66.200	3.00	86.420	4.30	123.800	5.00	172.900	7.40	213.120	8.50	244.900	9.50	273.600	11.30	325.440	13.40	385.520	13.40	385.520
1.0	2	.216	.128	22.3	.25	.193	.43	.340	.57	.443		1.13	.878	1.13	.878	1.39	1.075	1.60	1.243	1.79	1.392	2.12	1.647	2.53	1.963	
1.0	4	.529	.225	27.8	.42	.800	.71	1.350	.93	1.774		1.32	2.510	1.36	3.549	2.28	4.349	2.63	5.013	2.95	5.620	3.49	6.640	4.17	7.930	
1.0	6	.940	.310	31.3	.60	2.030	1.00	3.380	1.20	4.060		1.70	5.750	2.50	8.460	3.00	10.150	3.50	11.820	3.90	13.200	4.60	15.560	5.50	18.180	
1.0	12	2.750	.510	36.5	.80	7.920	1.40	13.850	1.80	17.820	2.40	25.740	2.60	36.640	4.50	44.580	5.20	51.470	5.80	57.420	6.90	68.310	8.20	81.180		
1.0	18	5.440	.770	41.6	1.20	23.500	2.00	39.180	2.60	50.910	3.60	70.500	5.00	99.900	6.30	123.400	7.30	143.000	8.20	160.580	9.70	189.960	11.50	225.170		
1.0	24	9.000	.990	44.0	1.40	45.360	2.40	77.800	3.20	103.700	4.50	145.800	6.30	204.720	7.80	252.720	8.90	288.360	10.00	324.000	11.80	384.220	14.10	456.840		
2.0	2	.383	.144	23	.27	.385	.48	.660	.62	.854	.88	1.219	1.25	1.722	1.53	2.108	1.77	2.438	1.98	2.728	3.32	4.320	4.70	5.850		
2.0	4	.863	.257	29.2	.47	1.112	.81	2.520	1.04	3.232	1.48	4.600	2.09	6.480	2.55	7.920	2.96	9.200	3.33	10.300	3.91	12.160	4.68	14.520		
2.0	6	1.440	.360	32.8	.60	3.450	1.10	5.700	1.40	7.260		2.80	14.520	3.40	17.620	3.90	20.220	4.00	22.800	5.20	26.950	6.20	32.140			
2.0	12	3.750	.620	39.3	1.00	13.500	1.70	22.950	2.20	29.700	3.10	41.810	4.30	58.000	5.40	72.830	6.20	83.620	6.90	93.150	8.20	110.700	9.80	132.300		
2.0	18	6.940	.860	42.9	1.30	32.470	2.22	54.950	2.80	69.950	4.00	99.920	5.60	139.880	6.90	172.360	8.00	199.840	8.90	222.360	10.50	262.330	12.60	314.750		
2.0	24	11.000	1.090	45.5	1.40	59.260	2.60	102.920	3.30	132.080	4.70	187.500	6.70	264.320	8.20	324.720	9.50	375.700	10.60	419.800	12.60	498.960	15.00	594.000		
3.0	2	.550	.150	23.7	.29	.594	.50	.996	.65	1.284	.92	1.817	1.29	2.552	1.59	3.150	1.83	3.620	2.05	4.070	2.43	4.813	2.90	5.742		
3.0	4	1.197	.276	30.0	.50	2.152	.86	3.720	1.12	4.800	1.57	6.757	2.22	9.570	2.72	11.740	3.15	13.580	3.53	15.200	4.18	18.000	4.98	21.480		
3.0	6	1.940	.380	33.4	.70	4.890	1.10	7.680	1.40	9.780	2.10	14.060	2.70	18.850	3.60	25.120	4.00	27.930	4.60	32.120	5.50	38.400	6.50	46.380		
3.0	12	4.750	.680	40.2	1.10	18.800	1.80	30.780	2.30	39.300	3.30	56.400	4.60	78.610	5.70	97.410	6.60	112.860	7.40	126.540	8.70	148.800	10.40	177.840		
3.0	18	8.440	.950	44.3	1.40	42.530	2.40	72.900	3.10	94.200	4.40	133.670	6.20	188.350	7.50	227.100	8.60	260.410	9.70	294.730	11.50	349.420	13.60	413.220		
3.0	24	13.000	1.170	46.7	1.60	74.880	2.80	131.050	3.60	168.480	5.10	238.680	7.10	332.280	8.80	411.840	10.10	472.680	11.30	528.800	13.40	627.120	16.00	748.800		
3.0	30	18.400	1.390	48.9	1.80	119.230	3.10	205.340	4.10	271.580	5.80	384.190	8.00	536.540	10.00	662.400	11.50	761.760	12.90	854.590	15.00	1,013.470	18.20	1,205.570		
3.0	36	24.800	1.640	51.1	2.10	187.480	3.60	321.400	4.60	410.680	6.60	589.250	9.20	821.370	11.30	1,008.860	13.10	1,169.570	14.60	1,308.490	17.30	1,544.540	20.60	1,839.170		

Slope, in feet per foot,

VELOCITY-QUANTITY TABLE No. 2.—For cobble gutter of design shown in figure 4.

V Value of "n" ranges from 0.0150 to 0.030. Satisfactory value of "n" is 0.018 for cemented cobble gutter and 0.030 for rough cobble type. That used in this table is 0.030. D is depth of water, in inches. A is area of wetted cross section, in square feet. R is hydraulic radius, in feet. C is from Kutter's formula for the same. V is velocity, in feet per second. Q is discharge, in thousand cubic feet per hour.]

Slope, in feet per foot.																							
D	A	R	C	0.001		0.003		0.005		0.01		0.02		0.03		0.04		0.05		0.07		0.10	
				V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
2	0.15	0.109	20.7	0.21	0.113	0.38	0.205	0.48	0.259	0.69	0.372	0.97	0.524	1.18	0.637	1.37	0.740	1.53	0.826	1.81	0.984	2.20	1.190
3	.34	.164	24.6	.31	.380	.55	.673	.70	.856	1.00	1.220	1.40	1.710	1.72	2.102	2.56	2.435	2.23	2.730	2.64	3.360	3.15	3.850
4	.60	.217	27.5	.40	.864	.70	1.512	.90	1.943	1.28	2.765	1.88	3.990	2.20	4.750	2.56	5.530	2.87	6.190	3.39	7.320	4.05	8.740
6	1.34	.321	31.7	.57	2.750	.98	4.730	1.27	6.130	1.79	8.640	2.53	12.210	3.10	14.950	3.59	17.340	4.02	19.400	4.75	22.920	5.67	27.370

VELOCITY-QUANTITY TABLE No. 3.—For concrete gutter of design in figure 5.

[Values of "n" range from 0.0149 to 0.0188. Value used in this table is 0.015. D is depth of water, in inches. A is area of wetted cross section, in square feet. C is from Kutter's formula for the same. V is velocity, in feet per second. Q is discharge, in thousand cubic feet per hour.] R is hydraulic radius.

D	A	R	C	Slope, in feet per foot.																			
				0.001		0.003		0.005		0.01		0.02		0.03		0.04		0.05		0.07		0.10	
				V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q	V	Q
2	0.150	0.109	55.6	0.58	0.313	1.01	0.543	1.29	0.700	1.83	0.991	2.58	1.398	3.18	1.715	3.67	1.983	4.11	2.220	4.87	2.628	5.79	3.133
3	0.340	0.164	62.8	0.80	0.433	1.39	1.710	1.77	2.200	2.51	3.100	4.390	4.40	5.380	5.69	6.220	5.70	6.970	6.74	8.240	8.04	9.830	
4	0.600	0.217	69.0	1.01	2.190	1.75	3.803	2.27	4.910	3.20	6.940	9.800	5.47	12.020	6.43	13.890	7.20	15.560	8.45	18.400	10.16	21.950	
6	1.340	0.321	76.9	1.38	6.640	2.39	11.520	3.08	14.850	4.36	21.020	29.650	6.14	29.650	7.55	36.400	8.72	42.060	9.76	47.100	11.54	55.740	66.440

VELOCITY-QUANTITY TABLE NO. 4.—*For tile pipe with smooth joints.*

[Value of "n" used is 0.015. D is diameter of pipe in inches. A is wetted area of cross section of pipe in square feet. R is mean hydraulic radius in feet. C is coefficient taken for S equal to 0.001. Q is discharge in thousand cubic feet per hour. The pipe is assumed to run 0.95D full.]

D	A	R	C	Slope, in feet, per foot.									
				0.001	0.003	0.005	0.01	0.02	0.03	0.04	0.05	0.07	0.10
				Q	Q	Q	Q	Q	Q	Q	Q	Q	Q
4	0.086	0.095	53.9	0.162	0.281	0.363	0.512	0.722	0.886	1.025	1.146	1.356	1.61
6	.193	.143	58.6	.485	.841	1.085	1.534	2.162	2.652	3.070	3.438	4.065	4.848
8	.343	.191	64.8	1.104	1.915	2.470	3.500	4.928	6.080	6.990	7.813	9.270	11.050
12	.771	.287	73.7	3.452	5.990	7.730	10.925	15.410	18.910	21.870	24.480	28.950	34.520
15	1.200	.358	77.9	6.360	11.030	14.230	20.130	28.380	34.820	40.260	45.100	53.350	63.600
18	1.734	.430	81.4	10.520	18.240	23.550	33.300	46.950	57.600	66.600	74.600	88.200	105.250

It will be noted that the trapezoidal open ditch has been assumed in computing capacity. This is by far the commonest type used in cross-section designs, although the dimensions vary within rather wide limits. This is supplemented by two ditches of the V type, one having a very flat slope. These indicate the transition in earth from the trapezoidal or dug ditch to the gutter type, which often can be made with the ordinary road grader. The common rectangular or "square" ditch, so frequently seen in some localities, especially in the southeastern part of the United States where sand clays abound, is not calculated. This type of ditch is not recommended for several reasons. In the first place there are very few soils that will stand with a vertical face, particularly if that face be presented to flowing water. Such materials as the loess of Adams County, Miss., and certain grades of sand clay in the Carolinas and Georgia are rare. Service tests indicate that such material will stand for years, but ordinarily nothing but a service test will disclose that characteristic, and no amount of examination appears to furnish sufficient data for a decision as to whether or not an earthy material may be counted upon to stand practically vertical. The safest assumption in design is to rely on no unusual qualities in the soil at hand and to construct a ditch on one of the approved designs used in the tables.

The V-shaped ditches have several favorable characteristics. They are not dangerous to traffic. They can be made with a grading machine and can be cleaned and maintained very largely with a grader, or for light work even with a drag. The highest velocity of flow in the ditch cross section occurs toward the side away from the road, and so the tendency to scour or wash, unless there be some disturbing obstruction, occurs first on the side away from the road and gives ample warning that attention is needed. These are the shapes that most closely approach common gutter design, and thereby lend themselves most readily to continued improvement by paving if the surface be advanced in type to warrant such a change.

The foregoing tables on page 7 are not applicable to short cross drains and culverts, because the condition of approach channels and outlets affect the capacity of these to a very great extent. Data for use in designing structures of this kind are furnished in other bulletins of the Bureau of Public Roads.

DESIGN OF SURFACE DRAINAGE.

Surface-drainage systems for roads consist of side ditches along road, paved gutters which are a development of side ditches and replace them, open intercepting ditches constructed to prevent water from reaching the road, and lateral or relief ditches to carry off the water which collects in the side ditches or in the intercepting ditches. Culverts and inclosed drains, which are constructed for the purpose of removing storm water from the side ditches or gutters, are essentially a part of the surface drainage system and are not to be confused with subdrains, which have an entirely different purpose.

CROWN.

The amount of crown which the surface of a road should be given in order to drain itself properly is very important in connection with surface drainage and one of the early elements of consideration in drainage design. But, since this feature is necessarily influenced by other considerations than efficient drainage, it will not be discussed at length in this paper. The Bureau of Public Roads has already published bulletins discussing the detailed design and construction of many types of improved road and reference may be had to these¹ in determining the amount of crown necessary for the various types.

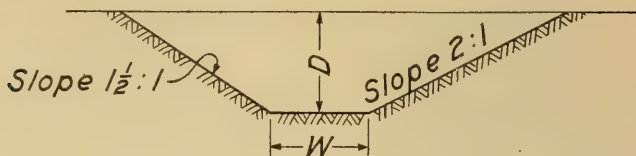
SIDE DITCHES.

Side ditches usually are necessary where roads are located in cuts or where they follow the natural surface of the ground. It is also frequently desirable to construct ditches approximately paralleling the road, even when in fill, in order to conduct water from a neighboring cut or berm ditch by a ready channel to some accessible natural drainage line. Tables 1A and 1B show the carrying capacity of ditches having various forms and slopes, and figures 1, 2, and 3 show the three cross-sectional shapes most commonly employed.

A ditch having the trapezoidal cross section shown in figure 1 has a greater carrying capacity for the same cross-sectional area, but unless the bottom be made relatively wide it erodes more easily than the ditches shown in figures 2 and 3. This section is adapted in general to locations where the slope is comparatively light and the amount of water to be drained is relatively large. For side ditches

¹ Office of Public Roads Bulletins 43 and 45; Yearbook separate 737.

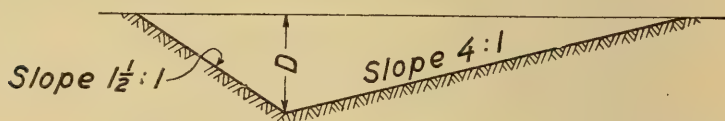
D is usually made from 1 foot to 1 foot 6 inches, with W sufficient to give the required capacity. Where the ditch is not located sufficiently far from the road to avoid danger to traffic, and the grade is steep, it may be desirable to increase W and diminish D, in order to secure the required cross-sectional area and at the same time prevent erosion.



SECTION OF EARTH DITCH

FIG. 1.

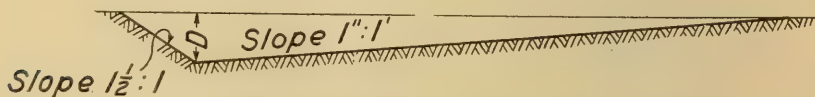
The section shown in figure 3 gives a ditch of comparatively small capacity, but the same amount of water flowing in a ditch of this shape will cause less erosion on steep grades than in a very narrow ditch of the cross section shown in figure 1. Another advantage of this wide, flat ditch is that it may be constructed easily and main-



SECTION OF EARTH DITCH

FIG. 2.

tained by means of a road grader, while the other types of ditches require more or less pick-and-shovel work. One of its principal disadvantages is that it must be extremely wide on light grades in order to carry any considerable quantity of water, and in deep cuts it may be very expensive to obtain the necessary width.



SECTION OF EARTH DITCH

FIG. 3.

Figure 2 shows a modification of the section shown in figure 3, which is intended to meet conditions intermediate between those described as being suited respectively to the other two sections.

From the velocity-quantity tables, pages 7 to 9, it is apparent that for a ditch of given cross section the velocity of flow is dependent upon (1) the quantity of water the ditch carries, and (2) the longitudinal slope of the ditch. The velocity which causes erosion

varies considerably with the character of the soil traversed by the ditch, and, since it is impracticable to describe soils in exactly comparable terms, no exact rules can be established for determining the safe velocity for water flowing in earth ditches. The heavy zigzag lines drawn through the tables are just below the maximum velocities which would ordinarily be considered safe for the most favorable soil conditions, and table 5 shows other safe velocities which may be assumed for given soil conditions.

TABLE 5.—*Safe maximum stream velocities for different soils and other materials.*

Kind of material.	Mean velocity in feet per second beyond which erosion is likely to occur.	Remarks.
Fine sand and silt.....	0.5 to 1.0	These values would apply to some alluvial soils.
Sandy loam, clay loam, and light clay.....	1.0 to 1.5	Average soil conditions.
Stiff clay and other firm soils (not subject to freezing).	1.5 to 3.0	These values should be used for only very resistant soils in warm climates.
Coarse gravel and crushed stone.....	3.0 to 5.0	These values apply to such materials as are ordinarily used for road crusts.
Cobble gutters sand filled.....	5.0 to 7.0	The sand filler would be retained only by virtue of the rough surface.
Cobble gutters grout filled.....	10.0 to 15.0	
Solid rock and concrete.....	15.0 to 25.0	

As an example of how the tables may be used, consider a side ditch of the cross section shown in figure 3, in moderately stable loam soil and let it be assumed that the ditch will drain the surface on each side for an average distance of 12 feet from the center, or that the total width drained is 24 feet. Also assume the maximum rainfall at 1 inch per hour, the maximum run-off at 100 per cent, the allowable velocity in the ditch at 1 foot per second, and the longitudinal slope of the ditch at 0.05 or 5 per cent. From table 1B we see that in order for the velocity not to exceed 1 foot per second, the depth of water in the ditch must not exceed about $1\frac{3}{4}$ inches, and that this depth fixes the capacity of the ditch at about 500 cubic feet per hour. Under the given assumptions, the allowable quantity of water would flow into the ditch in a distance of 250 feet, and, if a greater length of ditch must be drained without the water being turned off, some provision for protecting the ditch from erosion should be made below the 250-foot point.

In practice it frequently will be necessary to modify the computations by taking into consideration such contingencies as changes in the grade or curves in the alignment of the ditch, or the matter of water being turned into the ditches from intersecting roads or adjacent fields. Where the grade of a ditch flattens out in descending a hill, for example, the velocity of the water will be checked where the change occurs, and a part of whatever soil it has in suspension will be deposited. Curves in alignment produce a tendency for the water to cut sideways, away from the center of the curve, and for this reason water following along the inside ditch of a curved roadway is very liable to erode the shoulder, and eventually may undermine the road crust, unless provision be made to prevent this. In general, wherever there are marked changes in grade, it is good design to proportion the ditches accordingly, especially where a descending grade flattens out or a curve occurs in the alignment. This is a detail quite commonly neglected, but by observing it the velocity of the flow can be maintained sufficiently uniform to prevent both the deposit of sediment and the erosion of the ditch or grade. The practice of turning into side ditches water from adjacent fields and intersecting roads is very objectionable, especially on steep grades, and usually can be avoided. Where it can not be avoided, ample allowance for the additional water should be made in the computations.

In order to supplement the data contained in the tables a limited number of observations have been made on roads in several localities, with a view to ascertaining just how the erosion of side ditches actually is affected by different conditions of soil and grade. The sections of road selected for study were all so situated that the area drained by the side ditches consisted of only the roadway and the excavation slopes formed in grading the road. Studies were made in

Maryland, Ohio, North Carolina, and South Carolina, but the data so far secured do not warrant any attempt to take the locality into account in presenting the results. The conclusions which seem warranted at present may be stated briefly as follows:

1. Except where the soil is sandy, the run-off, so far as the roadway and slopes are concerned, should be assumed as 100 per cent of the rainfall.

2. For sandy soils the run-off varies considerably. Where the soil is as much as 3 or 4 feet in depth and the grade does not exceed 5 or 6 per cent, it appears that the surface run-off may usually be entirely neglected. For less depths of sandy soil the run-off may for present purposes be assumed as inversely proportional to the depth. This does not apply to soils consisting of very fine sand with a large percentage of silt, as such soils may be almost impervious to water and always erode very easily.

3. The power of soils to resist erosion is much less when the ditch is first constructed than later. This is true especially where vegetation is allowed to grow in the ditches.

4. Although the velocity of flow is independent of the length of ditch, the length affects the quantity of water passing any given point, and consequently affects the amount of erosion. Further, the tendency to erode on the steep section of a ditch, however short, will be practically the same as if the steep grade prevailed throughout the length drained.

5. The relative carrying capacity of differently shaped ditches appears to be indicated with a fair degree of accuracy in the velocity-quantity tables given on pages 7 and 8, though the observed data bearing on this point are not sufficiently complete to warrant an exact comparison.

6. It is theoretically possible to construct an earth side ditch of such cross section as to carry any given amount of water on any given grade without erosion. But the impracticability of widening the ditch indefinitely and the difficulty of maintaining a wide flat-bottomed ditch necessary to produce this result in practice usually serve to place a rather low limit on the capacity.

7. Where ditches of ordinary cross section are employed, the most satisfactory way to prevent erosion is to provide outlets for the water at proper intervals, to be determined in the manner already discussed.

8. Where for any reason outlets for the ditches can not be provided at proper intervals it usually is much more satisfactory to provide a paved gutter than to attempt to widen the ditch beyond the limits already described as conforming to good practice. The main reason for this is that a wide ditch, though properly designed and constructed, easily may become partially obstructed, so that the channel is effectively narrowed and erosion results. Once started this may increase very rapidly.

9. Side ditches may be protected to some extent from erosion by means of "bars," "breakers," or "drops" constructed across the ditch at such intervals that the slope from the bottom of one breaker to the top of the next one below does not exceed what is allowable for the soil and maximum flow of water involved. Such breakers frequently have been constructed of wood and sometimes of stone or concrete. Plate I is a photograph illustrating the method employed. It should be noted that where drops are used much difficulty is experienced sometimes in preventing the water from finding its way around their ends and cutting into the shoulders or banks.

10. Where doubt exists as to the necessity for employing a paved gutter it frequently is permissible to withhold decision until time can demonstrate whether or not the side ditch is adequate. This is true especially where the

gutter would be made of different material from the road crust, and constructed at a different time or by a different force of laborers.

11. The maintenance of side ditches consists in keeping them free from obstructions, and in reshaping them whenever this is desirable in order to prevent erosion. While a limited amount of vegetation may be advantageous to ditches on steep grades, it should not be such as to interfere seriously with the flow of water in the ditch. Where drops are employed they should receive frequent attention to see that they are not being undermined and that the water is not cutting around them. The design of drops sometimes calls for the use of brush, logs, saplings, cut stakes, etc., as these often are the only inexpensive local materials available in rural sections. While such designs, if carefully considered, may produce drops effective for a considerable period, their use is not recommended because of the great danger that the drop will break up under stress of unusual conditions and the floating parts seriously obstruct the ditch.

12. The following examples have been selected from notes regarding some of the existing side ditches which have been observed:

Example No. 1.—Side ditch on Rock Point road, Charles County, Md.:

Age of road, $1\frac{1}{2}$ years.

Original shape of ditch, flat V.

Width of roadway, 24 feet.

Width of gravel surface, 15 feet.

Average width drained by side ditch, including slope, 25 feet.

Character of soil, very light clay.

Slope of ditch (grade), 2 per cent.

Length from summit to where erosion begins, 400 feet.

Ditch empties into cross drain at 500 feet.

Example No. 2.—Same road and same conditions as example No. 1, except slope of ditch is 3 per cent:

Length from summit to where erosion begins, 200 feet.

Ditch maintained with considerable difficulty below the 200-foot point by means of wooden breakers.

Example No. 3.—Side ditch on Owings-Prince Frederick road, Calvert County, Md.:

Age of road, 4 years.

Original shape of ditch, flat V.

Width of roadway, 23 feet.

Sandy-clay surface.

Average width drained by side ditch including slope, $22\frac{1}{2}$ feet.

Character of soil, very light clay with small percentage of fine sand.

Slope of ditch (grade), 6 per cent.

Length from summit to where erosion begins, 100 feet.

At 300 feet the ditch has eroded 1 foot below the original section, and below 550 feet it is maintained with great difficulty by means of wooden breakers. Below 650 feet, in fact, the entire road has been washed out at least twice, notwithstanding the breakers.

Example No. 4.—Same road as No. 3.

Original shape of ditch, flat V.

Width of roadway, 24 feet.

Sand-clay surface.

Average width drained by side ditch, including slope, 25 feet.

Character of soil, mixture of light clay and fine sand.

Slope of ditch (grade), 6 per cent.

Length from summit to where erosion begins, 150 feet.

Below 200 feet it has been necessary to employ breakers, and below 400 feet the breakers have been washed out on several occasions and the ditch has become dangerous to traffic.

Example No. 5.—Same road and same conditions as No. 4, except width drained by side ditch, 13 feet:

Slope of ditch (grade), $1\frac{1}{2}$ per cent.

Length, 600 feet, no erosion.

Example No. 6.—Washington-Baltimore road:

Age of road, 5 years.

Original shape of ditch, wide flat V.

Width of roadway, 27 feet.

16-foot bituminous macadam surface.

Average width drained by side ditch, 16 feet.

Character of soil, sandy clay with considerable gravel.

Slope of ditch (grade), 4 per cent.

Total length of ditch, 900 feet.

Below 800-foot point the ditch has eroded slightly, but maintenance is very light.

Example No. 7.—Washington-Atlanta highway in North Carolina:

Age of road, over 5 years.

Original shape of ditch, irregular but approximates the cross section shown in figure 1, with average bottom width of about 1 foot.

Width of roadway, 24 feet.

Earth road.

Average width drained by side ditch, 18 feet.

Character of soil, clay loam.

Slope of ditch (grade), $2\frac{1}{2}$ per cent.

Length from summit to where erosion begins, 1,000 feet.

Water turned off at 1,100 feet.

Example No. 8.—Same road and same conditions as No. 7, except slope of ditch, 4 per cent:

Length from summit to where erosion begins, 500 feet.

Ditch becomes dangerous to traffic below 600 feet.

Example No. 9.—Same road and same conditions as No. 8, except soil is a very stiff clay and slope of ditch is $7\frac{1}{2}$ per cent:

Length from summit to where erosion begins, 500 feet.

Difficult to maintain ditch below 600 feet; water turned off at about 700 feet.

GUTTERS.

Where the grade of a road is so steep that the ordinary earth side ditches can not be maintained satisfactorily at a reasonable cost, or where earth side ditches would be unsanitary or appear unsightly, it is customary to provide paved gutters for removing the surface water. The point at which it is economical to change from earth side ditches to paved gutters on account of the steepness of the grade depends on the character of the soil and the amount of water to be

carried. The influence of these factors has been discussed under the heading "Side ditches."

The proper type of gutter to employ depends on a number of considerations. Due attention should be paid in its design to having it of adequate size and properly correlated with the other parts of the surface drainage. If a ditch on a steep grade be replaced at some point by a paved gutter, the latter should of course be designed in harmony with the ditch it replaces. If a paved gutter receives a heavy discharge from side roads or elsewhere, the necessary changes should be made to prevent flooding. Often the distance of the gutter from the surface affects its design and type. A gutter paved simply to prevent erosion, and situated perhaps 10 feet from the edge of the surface, does not require the bearing strength of a gutter immediately adjacent to the surface and used often as an effective part of the traveled way. The surfacing material itself sometimes affects the gutter design, inasmuch as principles of harmony and uniformity of surface must be considered; and occasionally proposed methods of construction of the wearing surface affect the design of the gutter. All of these details must be considered, as well as the general ones of available materials and economic cost.

Gutters may be constructed of Portland cement concrete, brick, cobble stones, angular fragments of stone, or other similar material. In some cases they are formed simply by constructing a curb along the edge of the road surface, as is done sometimes in city pavement construction. This method can be employed only where the road surface is made of material capable of withstanding the eroding action of water and where it is not important that the earth shoulders be kept open to vehicle traffic.

Gutters are made from 2 feet to 6 feet wide and from 3 inches to 10 inches deep, depending to a great degree on the type of design, and the size is governed by the same considerations as govern the size of earth-side ditches. That is, they should have a cross section sufficient to drain the road without danger of overflow, and, in order to determine this cross section, it is necessary to consider the area to be drained, the maximum rate of rainfall and run-off, and the character and slope of the gutter. Tables 2 and 3 give the capacity of gutters having various shapes, slopes, and cross-sectional dimensions. The values given in these tables were computed for cobble and concrete, respectively, but may be used in designing other type of gutters, provided the relative surface roughness of each type is properly considered. In Tables 6 and 7 will be found velocity-quantity figures for an alternative design for concrete gutters. In making the computations the cobble gutters were assumed to have their characteristic rough finish, and the concrete gutters a smooth,

even surface. In designing gutters it is well to bear in mind the following points:

1. It is not usually necessary to extend a gutter entirely to the top of a grade, because, as examples cited indicate, there usually is not water enough flowing in the upper part of the side ditch to cause erosion.

2. It is not usually economical to vary the size of the gutters on long grades so that they will have only the required capacity at all points; but changes may and should be made if any considerable change occurs in the required capacity.

3. All gutters should be sufficiently strong to withstand the impact caused by an occasional vehicle being driven into them, but unless they are capable of withstanding constant vehicular traffic they should be designed so as to discourage the practice of driving into them.

4. The grade of gutters should be made as uniform as practicable in order to prevent them from becoming partially filled by sedimentation, and should not be less than 1 in 200.

Brief directions for constructing the most common types of gutters follow:

COBBLE GUTTERS.

Cobble gutters are ones constructed of rounded water-worn stones, ranging in size from 4 to 8 inches in their longest dimension. The stones should be sound, durable, and fairly uniform in shape. The construction of the gutter should proceed about as follows:

First, excavate a trench to receive the gutter. The trench should have a width equal to the outside dimensions of the gutter and should be excavated to a depth of about 12 or 14 inches below the proposed grade of the gutter.

Second, spread sufficient broken stone or gravel in the bottom of the trench to give a depth of about 6 inches when thoroughly compacted. The broken stone or gravel should be of the kind ordinarily specified for macadam or gravel roads and should be compacted thoroughly with hand rammers.

Third, spread a layer of bedding sand over the foundation to such a depth that when the cobblestones are bedded into the sand and rammed thoroughly, they will form a gutter true to grade, line, and cross section. For cobblestones of fairly uniform size a depth of about 2 inches usually is sufficient for the sand bedding.

Fourth, place the cobblestones. In doing this the larger and more nearly perfect stones should be selected and placed true to line and grade in the edges and in the row which forms the lowest part of the gutter. All stones should be laid with their long diameter lengthwise of the gutter and should fit snugly one against the other. Each stone should be rammed until it no longer yields under the rammer, and any irregularities which may develop should be corrected by resetting the affected portions. While the ramming is in progress, sufficient coarse sand should be spread over the surface to keep the joints between the stones well filled. When the ramming is complete, the surface of the gutter should be uniformly true to line and grade. Wherever changes in the dimensions of the gutter are necessary, they should be made gradually, and not by abrupt off-sets.

Fifth, where the grade of a cobble gutter exceeds about 5 per cent, and the volume of water it must carry is at all considerable, the interstices between the stones should be filled with Portland cement grout instead of sand, as above described. A suitable grout for this purpose may be made by mixing

together 1 part cement, 2 parts sand, and sufficient water to give the grout a consistency about equal to that of ordinary cream. When the joints are grouted, the bedding sand should not extend above the center of any stone; because, if it does, the grout is very likely to crack and spall out.

This type of construction will give a gutter practically as strong as the road surface and may consequently be used in juxtaposition to

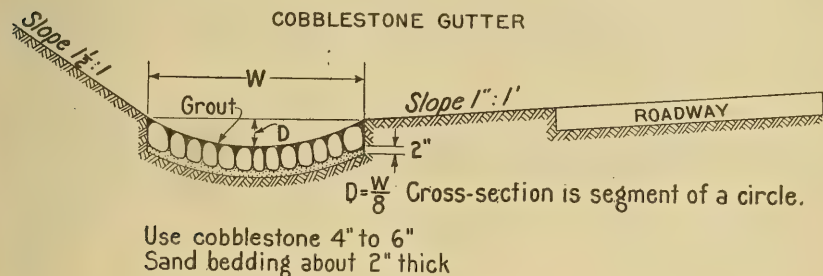


FIG. 4.

it. If there is little probability that traffic will use a gutter, naturally such heavy construction is not necessary. There are cases when adequate gutters may be built on a thin course of cinders with a sand bedding course. If the soil be not noticeably poor, 4 inches of cinders or gravel will be adequate. In some cases, on unusually favorable soils, such as sands or sandy loams, it may be possible to build immediately on the soil in place or with nothing more than the sand bedding course added.

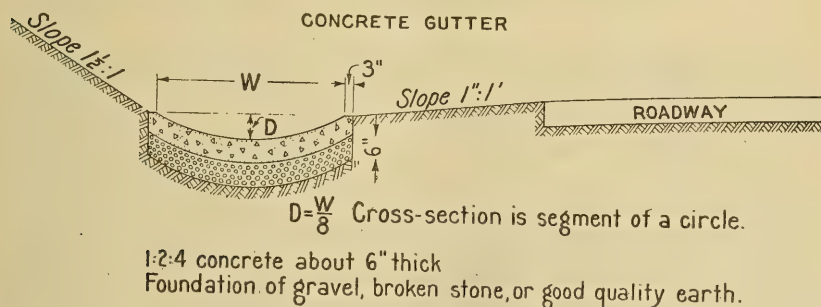


FIG. 5.

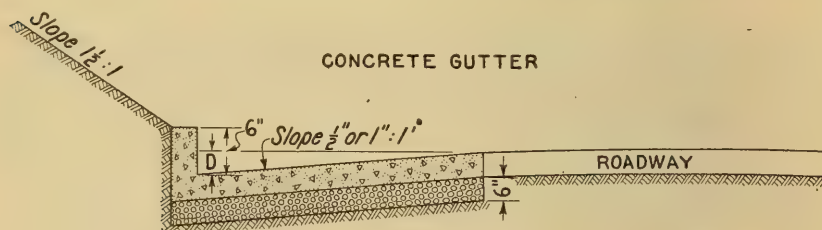
Figure 4 shows a typical cross section for a cobble gutter, and Plate I is a photograph showing a completed gutter which was constructed in accordance with the foregoing directions and which is now giving satisfactory service. Sand was used for filling the joints in this gutter.

CONCRETE GUTTERS.

There are two types of concrete gutters in general use. One has a curved cross section, as shown in figure 5, and the other is essen-

tially a sloping shoulder with a raised curb at the outer edge, as in figure 6. The first is adapted for use where the road follows the natural surface of the ground closely, and there is no especial difficulty in securing the necessary width for road and gutters. Where the road is located in a deep cut, on the other hand, or where for any reason it is especially desirable to utilize the gutter as a part of the road surface, the second type should be employed. The method of construction is practically the same for both types and may be described briefly as follows:

First, the foundation should consist of broken stone, gravel, or a good quality of earth brought to the required shape and thoroughly compacted by rolling or tamping, as in the case of cobble gutters. The location and probable demands on the strength of the structure determine the expense justifiable in any case. Where earth is used as a foundation in cold climates, great care should be exercised to see that it is well drained, as otherwise freezing may cause the gutter to heave.



1:2:4 concrete about 6" thick.

Foundation of gravel, broken stone, or good quality earth.

FIG. 6.

Second, the gutter paving should consist of concrete mixed in the proportions 1 part of Portland cement to $1\frac{1}{2}$ parts of clean coarse sand and 3 parts of crushed stone or gravel that will pass a $1\frac{1}{2}$ -inch screen and be retained on a $\frac{1}{4}$ -inch mesh screen. If the paving is merely to prevent erosion and will take no traffic a 1-2-4 mix may be used. The concrete should be mixed to a rather dry consistency so that it will hold its shape in the gutter, and should be thoroughly tamped until all the voids are filled and mortar flushes to the surface. The surface then should be brought to a smooth, uniform finish by striking off with a template shaped to conform with the cross section of the gutter and floating with a wooden float. In the case of the curb gutter, the mortar should be worked down into the face of the curb with a spade.

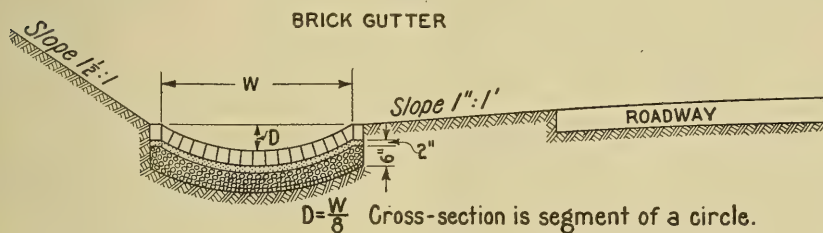
Fourth, joints extending entirely through the gutter should be constructed at intervals of about 20 or 30 feet. The joints may be made conveniently by means of bituminous felt strips placed in the gutter during construction. The bituminous felt, which should be about $\frac{1}{4}$ inch thick, is held in place with a template until the concrete is against it.

Fifth, after the gutter is finished as above described, it should be protected from the drying action of the sun and atmosphere for about two weeks. This is necessary to prevent the concrete from developing excessive shrinkage, cracking, and being damaged otherwise from too rapid drying out. One of the most satisfactory ways of protecting the concrete is to cover it with canvas as soon

after it is placed as can be done without marring the surface, and keeping the canvas wet constantly. After about 24 hours the canvas may be removed and replaced with an earth covering about 2 inches thick. This earth covering should be kept moist by periodic sprinkling during the two weeks it remains on the pavement.

BRICK GUTTERS.

Brick gutters may be constructed in a manner similar to that described for cobble gutters, or they may be made as a part of the road surface, as in the case of the second type of concrete gutter described. They are used seldom on country roads except in connection with brick pavements, and need not be especially discussed here, as the method of constructing the gutters should not be essentially different from that prescribed for the pavement.



Use vitrified brick.

Sand bedding about 2" thick.

Foundation of gravel or broken stone.

FIG. 7.

COST OF GUTTERS.

The cost of constructing gutters varies to a very great extent and depends principally on the design of the gutter, the construction methods employed, and the availability of materials. The amount of work to be done may also, of course, have an important influence on the unit cost, because this feature determines, in a great measure, the manner in which a force of laborers should be organized for carrying on the work. If the special conditions affecting any particular case are properly considered the following data should afford a fairly reliable basis for preparing cost estimates for the three types of gutters discussed above.

First, consider a cobble gutter of the cross section shown in figure 4, the foundation to be of crushed stone or gravel and the joints to be filled with Portland-cement grout.

Materials required for 100 linear feet:

Foundation, 0.20 cubic yard crushed stone or gravel.

Sand bedding, 0.07 cubic yard sand.

Cobble paving, 0.15 to 0.20 cubic yard cobblestones.

Grout, 0.05 to 0.08 barrel of cement, 0.20 to 0.30 cubic foot of sand.

Second, consider a concrete gutter of the circular section shown in figure 5,

the concrete to be mixed in the proportion 1 part cement, 2 parts sand, 4 parts crushed stone or gravel; the gutter to be given a 1 : 2 mortar finish and to have a total depth of 6 inches.

Materials required per square yard of gutter:

Portland cement, 0.25 to 0.30 barrel.

Sand, 0.070 to 0.080 cubic yard.

Crushed stone or gravel, 0.14 to 0.15 cubic yard.

Tar paper or bituminous felt, —.

(If the mortar surface is omitted, this would reduce the cost about 5 or 6 cents per square yard.)

Third, consider a brick gutter, figure 7, similar in cross section to the cobble gutter, the foundation to be of crushed stone or gravel, the paving to consist of vitrified paving brick laid on edge with the long dimensions in the longitudinal direction and the joints to be filled with Portland-cement grout.

Materials required per square yard of gutter:

Foundation, 0.20 cubic yard crushed stone or gravel.

Sand bedding, 0.055 cubic yard sand.

Paving, 40 paving brick.

Grout, 0.03 to 0.04 661 cement, 0.014 to 0.16 cubic feet of sand.

DROP INLETS AND CATCH BASINS.

Drop inlets and catch basins are used to conduct water from side ditches or gutters into underground drains or culverts. On country roads they are used most frequently on side-hill locations where the water collecting in the upper side ditch or gutter can be removed from the road at intervals by means of a culvert across to the lower side. Where the development contiguous to the road is suburban in character they may be required by a variety of conditions. Drop inlets usually are sufficient for this purpose and catch basins seldom are used in country-road work, except where it is especially desirable to prevent the silt and other foreign material carried by the water from getting into the underground drainage structure.

Where catch basins or drop inlets are to be used, their location and design are of especial importance. It is almost as common a fault, however, to omit them as to introduce them improperly into the drainage system. As indicated above, they are used to relieve the upper ditch or gutter and therefore have a close relation to the capacity of such gutter and its tendency to erode. Rightly placed, they afford a means of controlling the amount of water delivered by successive sections of gutter to the sections immediately adjacent, and enabling a gutter of uniform cross section to be designed for long slopes. In handling hillside drainage it is good practice to clear the gutters at the crest of the grade. If water has been brought across a flat to the top of a hill it is likely that in heavy rains the hillside ditches will be overcharged unless relieved at frequent intervals. Culverts placed under the road to provide such relief should have some form of intake that will direct water into them. The drop inlet may be used for

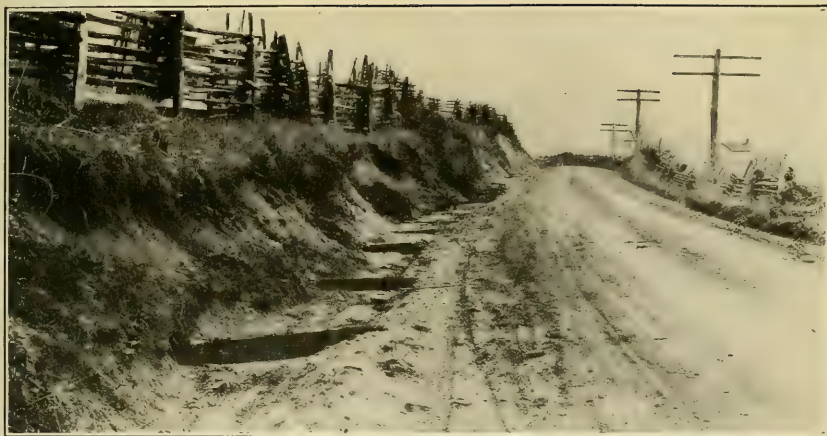
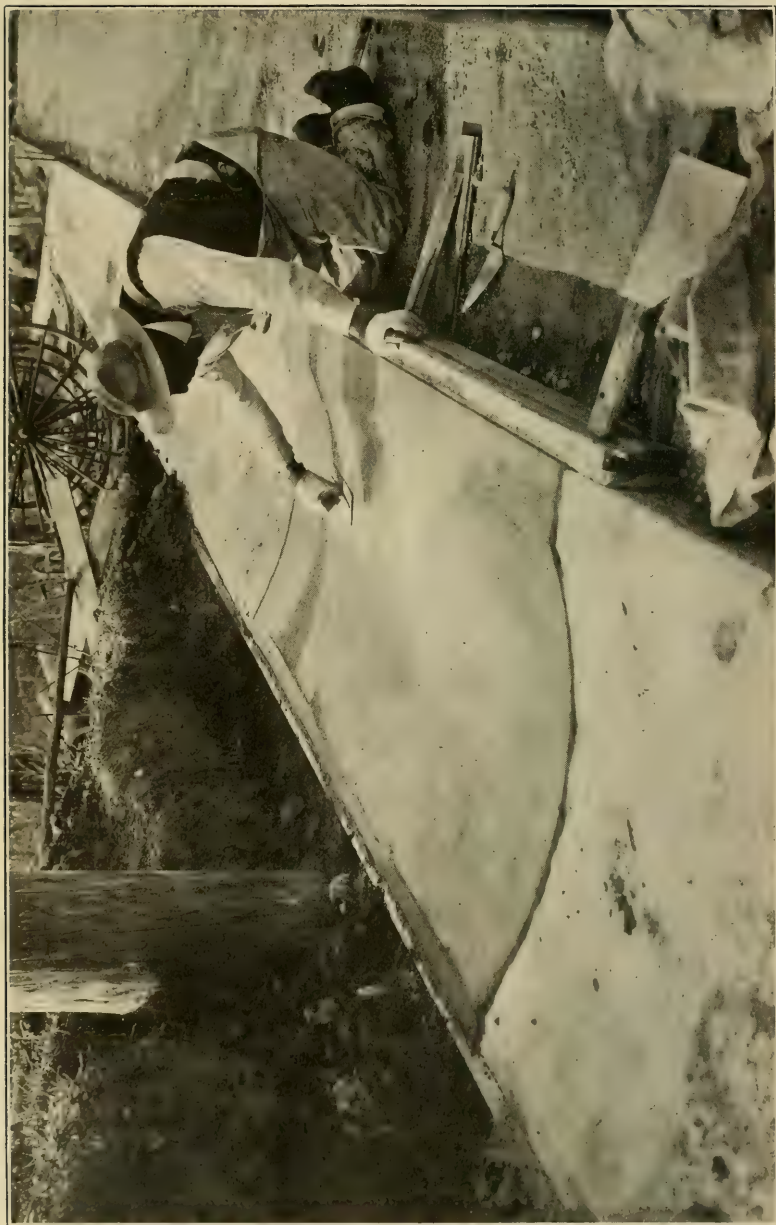


FIG. 1.—WOODEN WATER BREAKERS SET IN DITCH TO PREVENT SCOUR.



FIG. 2.—GROUTED COBBLE GUTTER.



FINISHING CONCRETE GUTTER.



FIG. 1.—BRICK GUTTER OF SATISFACTORY DESIGN FOR SMALL FLOW.



FIG. 2.—DROP INLET OPENING WITH CAST-IRON GRATING.



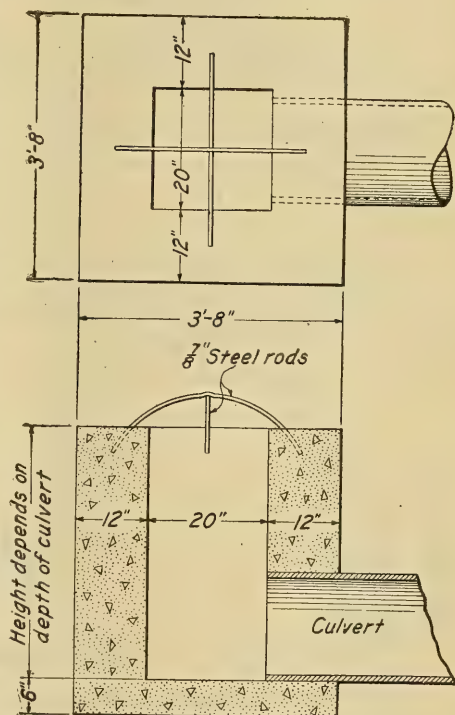
FIG. 1.—CONCRETE GUTTER AND CURB OF DESIGN SHOWN IN FIG. 6.



FIG. 2.—FRENCH TYPE OF SUBDRAIN WITH BELL AND SPIGOT PIPE AND STONE BACK FILLING.

this purpose, and the culverts and inlets should be placed at such intervals as to prevent the ditch from eroding or overflowing. The distance apart depends on the capacity of the gutter as designed. If the gutter be large enough it may be possible to use few cross drains or culverts and space them at intervals of several hundred feet. Under other conditions they may be required at intervals of as little as 50 to 100 feet.

The design should provide an inlet that will carry all that the cross drain will, and usually there is little difficulty in securing this condition. It is not essential that the inlet and cross drain be designed to clear the gutter if this be continuous, and the inlet entrance consequently may be a flat grating or opening designed to admit only a part of the flow. Usually, however, if the expense of inlets is incurred it is best to clear the ditches at each point, and the capacity of the culvert and inlet should be calculated accordingly. It is also good practice to make the gutter continuous, so that if the inlet becomes partly or temporarily clogged the water may continue along the gutter. On very steep grades it is well to design the inlet opening with a baffle on the lower side, so that all water flowing in the gutter to that point will be taken. In the baffle there should be a depression along the upper edge to provide relief in case the inlet becomes interrupted.



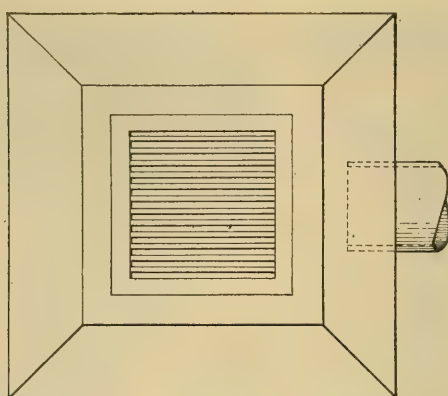
CONCRETE DROP INLET

Scale $\frac{3}{4}$ " = 1'-0"

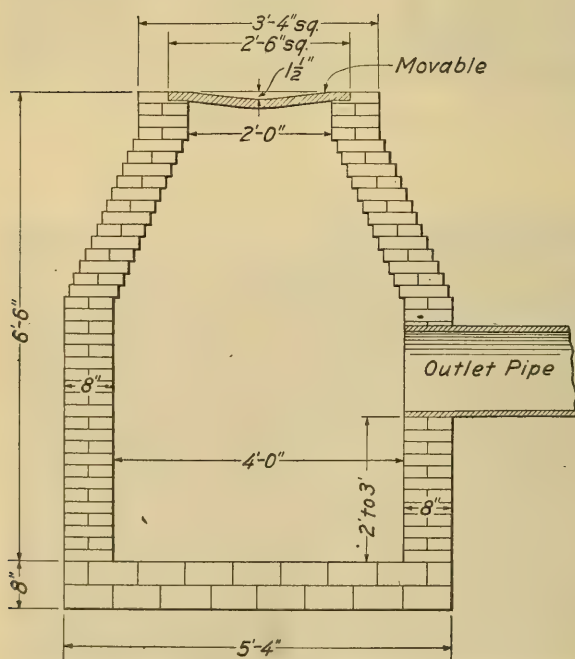
FIG. 8.

Owing to the difficulty sometimes had in clearing such culverts and inlets of obstructions it is well to give careful consideration to the probable conditions under which they will operate. If they are frequently under a head the inlet will run full but little difficulty will be experienced in keeping the culvert clear even at a very low slope; but if the prevailing storms are light and only a small flow occurs ordinarily in the culvert the pipe should be given sufficient

fall to clear. One-quarter inch to the foot, or about 1 in 50, will be sufficient under all usual conditions. Of course the pipe should be designed according to the proposed slope. Whatever specification is used for ordinary pipe culverts, cementing the joints under no circumstances should be omitted when drop inlets or catch basins are used, on account of the possibility of operation under head.



PLAN



SECTION

CATCH BASIN

FIG. 9.

The materials ordinarily used in constructing drop inlets and catch basins are Portland cement concrete, brick, or stone. Figure 8 shows a design for a drop inlet constructed of concrete and figure 9 a catch basin constructed of brick. The only essential difference between the catch basin and the drop inlet is in the space below the end of the culvert pipe which is provided to collect sediment. Drop inlets usually are somewhat smaller than catch basins, however, because the latter always must be large

enough to make cleaning practicable, and the former usually are designed to provide the necessary capacity for drainage only. Figure 10 shows a U-shaped head wall sometimes used for side-hill culverts

instead of the drop inlet and catch basin shown in figures 8 and 9. The dimensions shown in the figures are considered minimum for good practice, and it may be necessary to increase them where the volume of water to be cared for is large.

The photograph in Plate III shows a cast-iron grating suitable for covering either a catch basin of the design shown in figure 9 or a drop inlet of similar design. Where these structures are sufficiently far removed from the traveled way to obviate danger to traffic the cover design in figure 8 may be used. The practice of

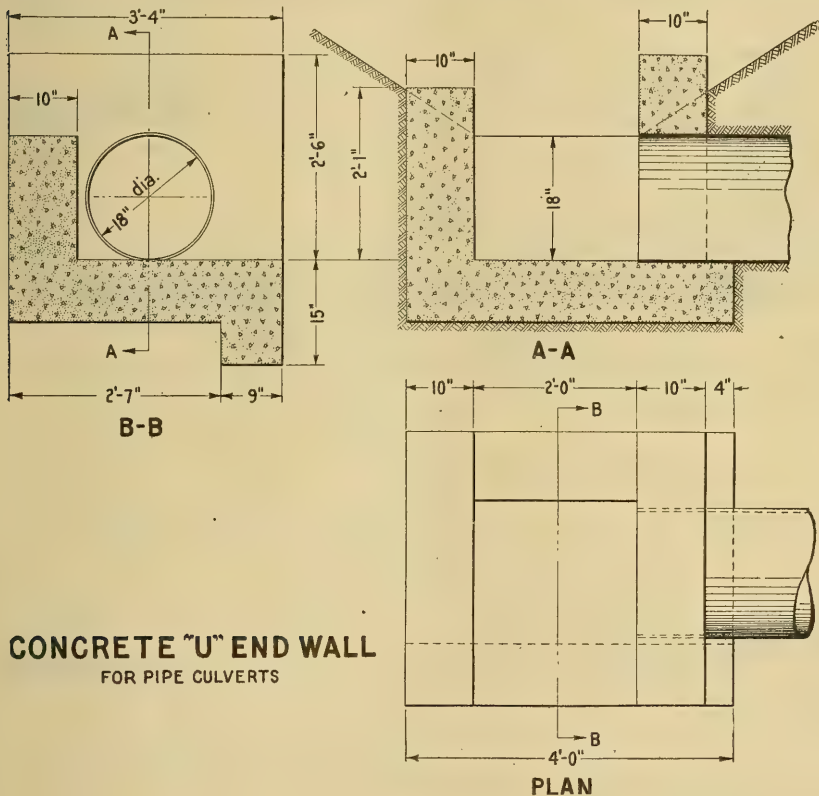


FIG. 10.

leaving the tops open always is objectionable on account of danger to animals, and also because the opening becomes obstructed with sticks, leaves, etc.

COSTS.

Such structures as are shown in figures 8, 9, and 10 usually may be constructed of 1:2:4 concrete at a cost of from \$12 to \$18 per cubic yard, including all form work. The labor cost per cubic yard should seldom exceed about \$10.

The cost of suitable cast-iron covers, where standard designs are employed, averages about 2½ cents per pound in place.

by tile drains; and fourth, by V-drain foundations. Each of these methods will be discussed briefly.

OPEN DITCHES.

Open ditches have been used frequently in some of the Southern States for subdraining roads through low flat sections. Ordinarily only one ditch is used, and it is located a few feet outside of and parallel to the road. This ditch usually is made about 2 feet wide and 3 or 4 feet deep, with the banks vertical. The material excavated from the ditch is used to build up the roadbed, and the surface water from the side ditches is turned into the deep ditch at convenient intervals.

The use of such ditches should be decided upon with care. There are ditches in the South, within the coastal plain, where sand clays and indurated clays occur a few inches underground, that have stood with vertical sides since the middle of the last century. They have been cleaned repeatedly and no doubt have become somewhat enlarged, but considering the cost of maintenance and the service given they have been entirely satisfactory. In other soils of a gravelly nature, however, the sides of such ditches would not stand, and the cost of keeping them clean would be excessive.

The open ditch is not to be selected for use in all locations. At best, when used near roads, it is dangerous and often unsightly. To keep it far enough from the traveled way to reduce danger to passing traffic to a minimum, it has to be deepened or lose somewhat its effectiveness. In general, this method gives fairly satisfactory results for a short time, provided the ditch be dug to a uniform grade and supplied with a suitable outlet. But a ditch of this kind, under ordinary conditions, soon will become obstructed by the banks breaking away and by the growth of vegetation, and is very seldom economical in the long run. There are few cases where a tile drain would not perform the work equally as well as an open ditch, and a tile drain possesses the advantage that when once completed, it will last indefinitely with practically no attention.

If open ditches are used for subdrainage they should be located carefully and constructed so they will perform their intended function. It is almost impossible to locate such a ditch that will not act somewhat as a surface drain, and in this event the possibilities must be considered. Frequently the ditches are designed to act in both capacities, but this practice is distinctly faulty if the depth of ditch is increased thereby much over what would be required for surface drainage alone.

DITCHES FILLED WITH STONE.

Ditches filled with broken stone or gravel sometimes are used as a substitute for tile drains to be described later. These have been used

in all sections of the country and, when properly constructed, usually have proved satisfactory for a considerable period of time. When such ditches are used it is common practice to place one on each side of the road immediately under the ditches. They are excavated to a depth of from 2 to 3 feet with vertical sides, and usually are made about 18 inches wide at the top or just wide enough for a man to work in them conveniently. To be effective they must have a uniform grade and be carried to a suitable outlet.

While common practice in this regard is as cited, it is not the best. Unless great care is taken in grading the material with which the ditch is filled, there is a marked tendency in all heavy storms for the stone-filled trenches to flush full of water heavily laden with silt and become clogged. A much better design is to lay one ditch down the center of the road, sufficiently deep to lower the water table enough at each edge and to cover it with the surfacing material. In

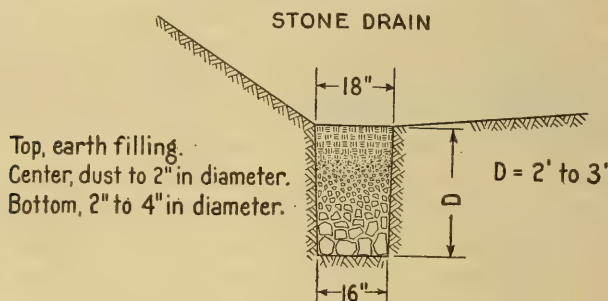


FIG. 11.

this way, the amount of storm water it accumulates by percolation is a minimum and it gathers no silt.

The stone or gravel used for filling these ditches should preferably be of a uniform size so that the percentage of voids will be high. A material consisting of rather large particles also is to be preferred because the individual voids in such material are large and are not so easily filled by deposits of silt.

If the subdrainage ditches are placed under the side ditches, the stone or gravel fill should be graded finer for about 6 to 10 inches near the surface, until the top 2 or 3 inches are sand, over which the natural soil and silt will tend to form a covering and so retard the filling and clogging of the lower stone. This grading of material is entirely unnecessary if the ditch is located under the surfacing. Figure 11 shows a typical cross section for a ditch of this kind. In the cross section large stones of a uniform size are shown in the lower part of the ditch and finer material in the upper part. This is a very effective arrangement, as the fine material near the top prevents silt from being carried down by the surface water and deposited in the interstices between the stone in the bottom layer.

TILE DRAINS.

Tile drains are, in general, much superior to either open ditches or ditches filled with stone for subdraining roads, and though generally more expensive than either open or stone drains, generally can be constructed at comparatively small cost. These drains, sometimes called French drains, are designed as shown in figure 11A. The depth of stone or gravel fill placed around and above the pipe varies according to the soil and ground water conditions. In some instances the stone fill is carried to the surface, in others it is omitted entirely. If a complete interception of underground flow is required in highly stratified material, it is best to fill the trench entirely with stone or gravel, but this is rarely necessary and when unnecessary is a waste of material. In any case, precautions should be taken to prevent

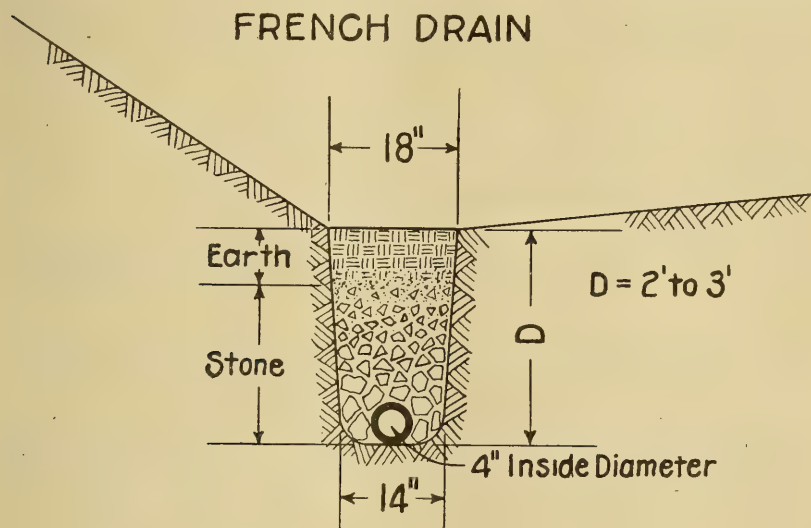


FIG. 11A.

silt from entering the pipe or clogging the stone fill. It usually is effective to lay tarred paper strips or pieces of broken tile over and around the joints when the trench is to be back filled with earth. If stone or gravel fill is used the same arrangement of sizes should prevail as for stone drain already described, care being taken to have an unbroken layer of sand on top of the finest stone.

Practice varies with regard to location of such drains. Ordinarily, one line of tile laid immediately under one of the side ditches and at a depth of 3 or 4 feet below the center of the road is sufficient, but where the soil is unusually retentive, two lines may be necessary. In some cases a single line of tile laid along the center of the road has proved satisfactory in retentive soils.

Where, on account of the design of the side ditches, or for other reasons, it is not desirable to place a tile drain under the ditch or

gutter, it may be located in the shoulder under the edge of the surfacing. The principal objections to locating the drain under the center of the road are that it is very difficult to back fill the trench in which the tile is laid so that no settlement will take place, and in case of injury to the tile repairs are hard to make and always interfere more or less with traffic. Where a center location is selected, corresponding care to insure proper alignment and grade and to prevent silting of the stone or pipe line should be taken. Where the road is located on a side hill it is usually satisfactorily subdrained by one line of tile placed on the up-hill side so as to intercept the flow of the ground water.

SIZE OF TILE.

The proper size of tile for any particular location depends upon the rate of the run-off and the slope of the tile. Where the topography is flat and no surface water is allowed to enter the tile directly it may be assumed safely that the maximum amount of water drained off in 24 hours would cover the area drained by the tile to a depth of about one-fourth inch, or that the maximum run-off would be about 35 cubic feet per hour for each acre drained. Where the topography is more or less broken or where springs empty into the tile, this maximum run-off may be increased very materially, and the probable influence of such factors as these always should be considered in fixing the size of the tile.

In order to determine the area a given tile will drain it is necessary to know how far out on each side of the tile the level of the ground water will be affected. In loose sandy soils this distance may be assumed to be about 100 feet, while in stiff clays that tend to retain water the level of the ground water may be practically unaffected at a distance out of only 20 or 25 feet. For most soils that require subdrainage it probably is safe to assume that the area drained on each side of the tile is from 30 to 50 feet wide. These distances are essentially affected by the depth at which the tile is laid. To develop the highest service in sandy soils the depth should be from 3 to 4 feet, while in stiff clays the depth should not exceed $2\frac{1}{2}$ to 3 feet. Where deep freezing is likely to occur and heaving or disalignment of the tile can be expected, it should be laid deeper, of course, and the number of lines increased if necessary to reduce the ground water peak between them.

Table 4 shows the sizes of tile required to carry various amounts of water. An examination of this table will show that rarely under conditions ordinarily encountered in road work need the diameter of the tile be greater than 6 inches, and that for most conditions a diameter of 4 inches is sufficient. No matter how small may be the amount of

water to be drained off, the diameter of the tile never should be less than 4 inches, because experience has shown that tile having a smaller diameter is very liable to become obstructed by sediment. The larger diameters given in the table generally are used only where it is necessary to admit more or less surface water directly into the tile, or to provide for some unusual flow from springs.

CLAY TILE.

Clay tile of the diameters shown in Table 4 is manufactured in almost every section of the United States. The ordinary farm tile, without the bell joints, is the kind most generally used for subdraining roads, and is generally satisfactory when laid at the side of a road where it will not be subjected to heavy loads. The tile may be either round or hexagonal in cross section and should be straight longitudinally, well burned, and free from cracks. The nominal section lengths are 12 inches for the smaller sizes and 2 feet or 2 feet 6 inches for the larger sizes. In practice, the lengths generally are made slightly in excess of the nominal to allow for a small amount of breakage. The ends always should be cut square in manufacturing so that successive sections may fit together snugly, but seldom does this condition exist. To make a good fit it is necessary at the time of laying to turn the tile over until the ends make the snuggest joint. If the cost of bell tile is not prohibitive they may be used to advantage in place of butt-joint tile.

Table 8 gives the average weight and the average number of feet in a carload for the various diameters of field tile. The costs at the factory are subject to more or less variation, and freight charges on tile have been relatively high, so that the costs of pipe delivered at railroad points some distance from the factory are so constantly variable that tabular figures are of little value. Where more than one size of tile is shipped at the same time, the amount in a carload may be increased and the freight per ton decreased by nesting the different sizes.

TABLE 8.—*Cost and weight of drain tile.*

Inside diameter.	Average cost per 1,000 feet f. o. b. factory.	Average weight per foot.	Average number of feet in a carload.	Inside diameter.	Average cost per 1,000 feet f. o. b. factory.	Average weight per foot	Average number of feet in a carload.
<i>Inches.</i>		<i>Pounds.</i>		<i>Inches.</i>		<i>Pounds.</i>	
4.....	\$15.00	8	6,500	12.....	\$95.00	36	1,000
5.....	22.50	10	5,000	15.....	140.00	50	700
6.....	27.50	12	4,000	18.....	245.00	72	400
8.....	47.00	18	2,500	24.....	370.00	115	300
10.....	67.00	28	1,600				

CONCRETE TILE.

Concrete tile is made from Portland cement and sand or fine gravel and may be substituted for clay tile wherever conditions are such as to make the use of concrete economical. The only exception to this rule is that where the water a tile is intended to carry contains any considerable quantity of either alkali or acid clay is preferable to concrete, because concrete may be destroyed quickly by strong alkali or acid, while these materials do not affect clay tile seriously. Machines for manufacturing concrete tile may be purchased for from \$40 to \$100 and may be operated either by hand or by a suitable engine. Table 9 shows the size, weight, and quantities of materials required for concrete tile of various diameters, and the following list of suggestions are practically sufficient to serve as a guide in the manufacture of such tiles.

TABLE 9.—*Concrete tile.*

[Straight tile—concrete mixed in proportion 1:3.]

Diameter.	Thick- ness.	Weight per foot.	Material re- quired per 100 feet.		Diameter.	Thick- ness.	Weight per foot.	Material re- quired per 100 feet.	
			Ce- ment.	Aggre- gate.				Ce- ment.	Aggre- gate.
<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>Bbls.</i>	<i>Cu. yds.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>Bbls.</i>	<i>Cu. yds.</i>
4.....	3/4	10.6	0.67	0.30	9.....	1 1/2	38.6	2.44	1.09
5.....	3/4	13.1	.83	.37	10.....	1 1/2	42.6	2.72	1.20
6.....	3/4	15.3	.97	.43	11.....	1 1/2	46.5	2.96	1.31
7.....	3/4	21.3	1.36	.60	12.....	1 1/2	50.4	3.20	1.42
8.....	1 1/8	31.2	1.98	.88					

1. Use a reputable brand of Portland cement known to conform with some standard specification, such as that of the United States Bureau of Standards, published in their bulletin No. 33.

2. The sand used as aggregate should be clean and graded in size from fine to coarse, with the coarse grains predominating. For the smaller sizes of pipe all the sand should pass a $\frac{1}{4}$ -inch mesh screen, but for the larger sizes it is economical to have the aggregate consist partly of fine gravel that will pass a $\frac{1}{2}$ -inch mesh screen. The proportion of gravel to sand should not be greater than 2:1.

3. The proportion of cement to aggregate should be about 1:3, but if the sand be inferior in any respect the amount of cement should be increased.

4. In making the tile, the concrete should be tamped into the forms so that no open or porous spaces are left, and the consistency of the concrete should be such that this can be done with comparative ease.

5. After the tile is finished and the forms removed it should be protected from the drying action of the sun and air and kept wet by sprinkling for at least seven days. Then the tile should for about 60 days be left in a protected place before it is used.

6. The cost of concrete tile depends on the cost of the materials of which it is composed and the cost and efficiency of labor. These are so variable in different localities that figures of general value can not be given. In general, the cost of concrete tile probably would average slightly greater for the smaller sizes and slightly less for the larger sizes than that of clay tile.

LAYING THE TILE.

In laying the tile work should begin at the lower end of the drain and proceed up hill when bell tile is used, and, in general, the work of excavating, laying and back filling should follow this rule, so that the various steps may be taken and the ditch drained at all times. To insure that the tile is laid true to grade, it is necessary to employ grade stakes, which are usually set by means of an engineer's level. These stakes should be spaced about 50 feet apart and offset sufficiently far from the line of the drain not to be disturbed while the ditch is being excavated. The excavation ordinarily is carried down to within a few inches of grade with plows, picks, shovels, etc., and the bottom of the trench is finished with a tile scoop. In handling the scoop great care must be exercised in order to bring the bottom of the ditch to a uniform grade and at the same time scoop out a properly shaped trench to receive the tile.

The tile should be laid as the ditch is completed, and each section should be turned until the ends fit together closely. Small openings at the joints, due to slight unevenness of the ends, are permissible, provided they are made to come in the bottom of the tile, but any opening more than about $\frac{1}{4}$ -inch wide should be covered with a piece of broken tile, cement mortar, or heavy tar paper. In the case of fine sandy soils, all joints should either be wrapped with cloth or tar paper. This is necessary in order to prevent sediment from being carried into the tile. Wherever two drains come together, the junction should be made preferably by means of T or V branches, because, when it is attempted to cut straight sections of tile to fit an angle, one section is very likely to project into the other and cause more or less obstruction. In case it is necessary to use straight tile on curves the joints should be covered with pieces of broken tile. Curves in a tile drain always should be as gradual as the location will permit, and should be avoided if possible.

As soon as the tile is laid it should be covered carefully to a depth of 5 or 6 inches with loose earth to hold the different sections in

proper position and to prevent displacement of the pieces of tile used for covering the joints. The back filling then may be completed, when convenient, with plows and drag scrapers, and after the surface over the drain has finished settling, it may be smoothed to the required shape with a road grader or a split-log drag.

If the drains are laid in the center of the road the back fill should be rammed carefully and firmly just as soon as enough has been placed to protect the pipe from displacement and damage. The back filling then should continue in layers, each one being rammed to provide so far as possible against settlement.

Where tile drains are constructed through unusually retentive soil and it is desired to secure the maximum efficiency from them, the trench should be back filled with crushed stone or gravel for 6 or 8 inches around and above the pipe. The proper method of making a back fill of this kind is indicated in the typical specification on page 81.

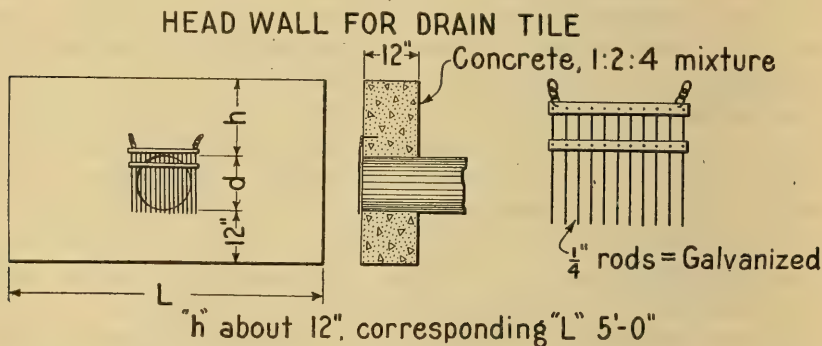


FIG. 12.

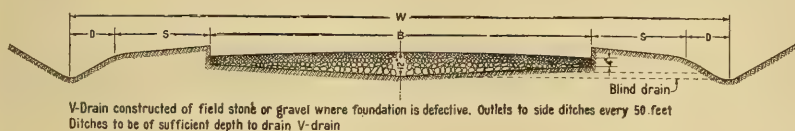
TILE-DRAIN OUTLETS.

Figure 12 shows an outlet for a tile drain protected by means of a head wall. The head wall prevents the end of the drain from being undermined and destroyed and also holds the earth in place at that point. The swinging screen over the end of the tile, which is shown in the figure, is intended to prevent rodents and other small animals from obstructing the tile with nests during dry seasons. In the past, outlets have not always been protected in this way and as a result trouble has been experienced frequently.

Satisfactory head walls may be constructed of stone, brick, or concrete. Wooden boards also have been used for this purpose, but are subject to the disadvantage that they must be replaced every few years, while the other materials are practically permanent. The screen over the end of the tile may be made of steel rods sharpened at their lower ends, and is suspended from the head wall by means of staples and links.

COST OF CONSTRUCTING TILE DRAINS.

The cost of laying tile drains, including necessary ditching and back filling, varies largely on account of variations in costs of material and labor, as already indicated. Where stone occurs in the ditch, or where any other condition makes excavation unusually difficult, the cost will be increased substantially. Where the soil is unusually soft, it is necessary sometimes to place boards in the bottom of the ditch to keep the tile from settling out of line, and in this case the cost of laying the tile, including the purchase of the boards, will be increased still further. In the rare cases where the conditions are such as to make it desirable that the ditch be entirely back filled with crushed stone or gravel so that the tile may do its work to the best advantage the cost of stone or gravel may be considerable. The additional cost of handling such cases would depend, of course, on the availability of the materials used in the back fill. In some cases the total cost, including all labor and material, has exceeded \$50 per 100 feet, although \$10 to \$12 per 100 feet are commoner figures for ordinary tile drain.



V-DRAIN

FIG. 13.

Suitable head walls and outlets for tile drains may be constructed at small cost. The design shown in figure 12 ordinarily can be built at a cost not to exceed \$5 or \$6. In some cases stone masonry may be employed at even a smaller cost.

V-DRAINS.

The V-drain shown in figure 13 and Plate V is especially adapted to localities where field stones can be obtained cheaply and in abundance. This type of drain is very effective when constructed properly and has the advantage that in addition to draining the subgrade of the road it provides an excellent foundation for the road surface. Its first cost is high when compared with the various types of side drains, but usually is much lower than the cost of side drains and Telford foundation combined. The latter comparison is, in general, the more reasonable one to make, because under favorable conditions a V-drain may serve to replace the combination of Telford foundation and side drains, and would be used seldom, if ever, where only drainage is needed to produce a stable foundation.

As shown in the cross-section drawing, figure 13, the V-drain is formed by excavating the subgrade of the road so that its cross section will have the shape of a flat V. This V-shaped trench is filled with field stone of all sizes from 6 to 8 inches in diameter down to pebbles only about 1 inch in diameter. The larger stones are placed in the center and lower part of the trench, while the smaller are placed on top and near the edges. It usually is necessary to spread the stone in two or more courses, so that it may be compacted to form a firm, unyielding foundation for the road surface. The compacting should be done with a power roller weighing about 10 tons, but should not be carried to such an extent as to fill the interstices between the stone in the lower part of the drain and thus prevent water from finding its way along the trench.

Some designs for V-drain, in order to save stone, require that the drain be carried out practically to 0 depth at the extreme edges, so that the stone or other road metal is practically without drainage at those points.

When V-drains of this design have been used in northern localities difficulty has been experienced with the edges of the road crust heaving in the spring. Probably this is due to the freezing of accumulated water near the edges of the drain. Such water will accumulate in the interstices as a result of shallow thaws that do not free the deeper areas of frost. The melted snow can not run off and fills the upper layers of the V-drain, especially near the edges, until the voids are too full to allow expansion on freezing. The result is that during succeeding freezes the edges of such drains will heave. The remedy is to increase the depth of V-drain at the edge and to provide drainage close to the surface through the shoulder so that such drains certainly will clear with the shallow thaws and permit water to flow freely from the V-drain. Experience indicates that the depth of V-drain, in addition to the surfacing material, should not be less than 4 inches at the edges, and that a depth of 6 or 8 inches is better.

Outlets for conducting water away from the V-drain should be provided at all low points in the grade. These outlets may consist of tile running from the lowest point of the V to a culvert or cross drain, or of ditches filled with the same kind of material as that composing the V-drain and running from the lowest point in the V to any lower point outside of the road where they may empty. In low flat sections, it frequently is difficult to provide suitable outlets for drains of any kind, and because V-drain foundations give the appearance of being very stable, whether or not outlets are provided, this feature sometimes is neglected in their construction. The result of such neglect is that water collects at low points in the grade and the roadbed at these points becomes excessively soft, and both roadbed and surface soon are badly out of shape.

COST OF V-DRAINS.

The most expensive feature of constructing a V-drain foundation is to collect and haul the field stones. The conditions affecting this part of the work seldom can be compared for different projects, even in a general way, and any cost data that might be given here would be more likely to prove misleading than otherwise. After the stones have been collected and hauled, the additional work required to put the foundation in shape usually is very slight, and its cost should not exceed a few cents per square yard. The cost of preparing the subgrade to receive the stones is discussed on page 51.

FOUNDATIONS.

In order to avoid confusion in the following discussion, the term foundation will be used to designate a specially constructed artificial base upon which the road surface or crust rests, and the term subgrade will be understood to mean that part of the roadbed, composed of natural earth or other similar material, which supports either the foundation, or in the absence of a foundation, the road crust. This distinction is purely arbitrary and is made simply for convenience.

The purposes of a foundation are, first, to aid in distributing the pressure due to wheel loads concentrated on the road surface so that the intensity of pressure on the subgrade will not exceed its safe unit bearing power, and second, to prevent, if possible, the crust of the road from being disturbed by the upward pressure of the subgrade due to the action of frost, ground water, or other disturbing influence. The relative extent to which these respective purposes should govern in designing a foundation depends on the character of the road crust and of the material composing the subgrade as well as on climatic conditions. For example, in the case of a pavement consisting of comparatively small blocks, such as vitrified brick, bonded to each other very slightly or not at all, an entire wheel load might be concentrated on only a few square inches of foundation, in which case it would be necessary for the foundation to take care of practically the entire distribution of the load. On the other hand, a monolithic pavement or a pavement in which the individual units are well bonded together might distribute the wheel loads sufficiently to obviate all necessity for further distribution by the foundation and if adequate drainage were provided and there were no danger of heaving of the subgrade, the foundation might be omitted entirely.

LOADS.

The heaviest vehicle that ordinarily has passed over a public highway heretofore is the 15-ton traction engine. Such engines usually are so designed that the rear axle carries about two-thirds of the total weight, which arrangement gives a concentrated pres-

sure on the road surface of about 5 tons under each rear wheel. The use of much heavier equipment is in sight, however, and unless some regulations be passed to prohibit it the occurrence of 10-ton or even heavier motor trucks on our local highways adjacent to large cities or between large centers that are only a few miles apart may become common.

Slight irregularities in the surface, due to faults in construction or developed by the wearing action of traffic, have the effect of producing impact under moving wheels and this action serves substantially to increase the pressure to be distributed by the road crust and foundation. On account of the impact which they produce swiftly moving motor trucks are sometimes more severe on road foundations than the heaviest traction engines, and if an improved road is to be subjected to any considerable volume of motor-truck traffic the impact feature should be given especial consideration when the road is designed.

In assuming the maximum wheel load for any particular road a reasonable allowance should be made for future increase. Since motor trucks have come into use there has been a constant tendency to increase both their rates of speed and the loads they carry, and it is quite probable that this tendency will continue. Furthermore, many roads not now subjected to motor-truck traffic will attract such traffic after they are improved, and this possibility always should be considered. Increase in the volume of traffic also may be an important factor, because a foundation ample to support an occasional heavy load might fail soon if the same load was often repeated.

DISTRIBUTION OF PRESSURE.

The manner in which pressure due to concentrated loads is distributed by the various materials used in road construction never has been fully investigated, and any assumptions regarding this point that may be made at present would be purely conjectural and of doubtful value. In the past engineers have made the questions of when a foundation should be employed and of how it should be designed wholly matters of judgment, and few, if any, rules have been formulated to aid even in making the judgment consistent for different conditions and materials. This lack of method is due directly to the absence of accurate knowledge concerning the cone of dispersion and pressure distribution under concentrated loads, and until further experimental data are obtained the design of road foundations necessarily must be based on rather uncertain empirical information so far as comparing the efficiency of different materials and methods of construction is concerned.

BEARING POWER OF SOILS.

On account of the uncertainty regarding the manner in which pressure due to concentrated loads on a road surface is distributed by means of the road crust and foundation, very exact knowledge concerning the bearing power of the soil composing the subgrade would be of small advantage in designing foundations. Such information would become of value only if a minimum bearing power were known, taking into consideration the effects of changing soil moisture. The most that can be done is to compare, in a general way, the soil conditions anticipated in the design with similar conditions on successful projects already completed and to consider known failures, the causes of which have been ascertained.

Such tests as have made for the purpose of determining the bearing powers of different soils have given more or less contradictory results, but all have shown a very wide variation for soils of practically the same character tested under identical circumstances. The following table gives averages deduced from available test results and may prove helpful in applying knowledge gained by experience in designing and constructing road foundations to similar work where the soil conditions differ from those already encountered:

TABLE 10.—*Safe bearing powers for different soils.*

Kind of soil.	Range of bearing power (pounds per square inch).	Kind of soil.	Range of bearing power (pounds per square inch).
Dry clay.....	50 to 80.	Moist loam.....	3 to 10.
Moist clay.....	6 to 50.	Dry gumbo.....	15 to 30.
Sand or gravel.....	25 to 85.	Wet gumbo.....	1 to 10.
Dry loam.....	10 to 20.	Marl.....	Same as clay.

This table indicates the extremely wide range of the available data and gives some idea of the value of judgment by the engineer in designing road foundations. It also demonstrates that figures in the matter are of little use with the very limited knowledge at our disposal.

Under the conditions ordinarily encountered in road work, the soil composing the subgrade is liable to become at least slightly moist, due to capillarity, even when the road surface is perfectly water-tight, and the effect of moisture in lowering the safe bearing power of the soil is an important consideration in determining whether a foundation is necessary and, if so, how it shall be designed.

The effect of capillarity can not be stated definitely, but that it has an influence on the condition and physical characteristics of the surface of the natural soil is certain. The amount of influence depends on meteorological conditions without and on various properties

within the soil, such as size and grading of soil particles, presence of organic matter, mineral salts, colloids, etc. Some of these properties produce opposite effects. The following table shows the height to which capillary water rises in certain soils in one day.

TABLE 11.—*Height to which capillary water rises.*

	Inches.
Light sandy soil.....	14
Gravelly soil.....	16
Decomposed granite (loam).....	21
Heavy granite loam.....	16
Heavy clay loam.....	11
Heavy lava ash.....	16
Pure sand.....	9

In one day the capillary water moves upward about one-half its apparent final limit. In three days it moves about two-thirds its apparent final limit. In some soils the movement upward in the first two hours is as high as one-third of its movement for 30 days. In pure sand it rises in one-half hour approximately one-half as high as in one day and in one day about 70 per cent as high as in 12 days. The movement is more rapid at the start in light soils, and slows down rapidly. After three days the movement is exceedingly slow in pure sand. In heavy soils the movement is uniformly slower and more sustained. In light soils the per cent of water in the soil decreases rapidly with the height above the source, while in some heavy soils the moisture content is strikingly uniform at different depths. Horizontal capillarity occurs with much faster water movement and greater uniformity of moisture content. The speed and distance varies with different soils and ranges from 7 to 33 feet in the first 24 hours.¹

The action of capillarity indicates that if water is to stand or flow along a road embankment for even a few hours, regard must be given to the height of the subgrade above the water line, and the lateral distance of the water course from the road crust or foundation. Assuming that the supply of free water will not endure more than one day at a time, it is apparent that a height in the subgrade of 18 inches above the water line will insure that the moisture content of the surface is not increased. Where the free water is present at a considerable distance to one side this height may be safely reduced. Shallow ditches a short distance from the center line tend, by horizontal capillarity, to increase the water content of the subgrade at a higher level than deep ditches similarly located. If the grade be through standing water or against a continuous source of free water so that the soil remains moist continuously, capillarity will lift the

¹ Capillary movement of soil moisture. Unpublished report of Riverside Exp., 1915-1917. W. W. McLaughlin.

water about four and one-half times higher than in dry soil¹, and this fact must be considered in designing cross section and grade across swamps, marshes, or against irrigation or drainage ditches in which water is present for long periods. These conditions affect the design or cross section and the establishing of grade in places where the presence of free water is foreseen or where run-off is expected to be slow and considerable, if the full bearing power of the natural soil is to be developed. If, because of immediate local conditions, the design of cross section can not be made to meet the above requirements, then special drainage should be provided or additional bearing value provided through some suitable treatment.

The way in which the subgrade is prepared also, of course, affects its bearing power to a very considerable extent. In fact, the exercise of proper precautions in the matter of draining and compacting a roadbed sometimes may give the subgrade ample stability for directly supporting the road crust, where otherwise, if these features were neglected, an expensive foundation might be required in order to afford the same degree of stability.

INFLUENCE OF ROAD CRUST.

The considerations that should determine the form of support to be provided for any particular type of road crust are (1) whether it is practicable to make the crust sufficient to distribute wheel loads so that the safe bearing power of a well-prepared subgrade will not be exceeded, (2) the relative cost of increasing the depth of the crust so as to take care of the necessary distribution, where this is practicable, as compared to the cost of providing a suitable foundation of cheaper material, (3) the damage that would result to the road surface in case of slight settlement of the subgrade.

All of these considerations depend largely, of course, on the character or type of road crust to be employed. Where the crust is to be of Portland-cement concrete, or some similar type capable of distributing adequately the pressure due to concentrated loads the foundation evidently may be omitted, provided the crust is made sufficiently thick to take care of the distribution of load. In the case of sand-clay, gravel, and macadam, furthermore, slight disturbance of the subgrade might not result in any very serious injury to the surface, because the materials forming the crust which might be disturbed would be rebonded soon by the action of traffic. With any of the types mentioned, however, it might be more economical to construct a foundation of cheaper material than to provide the additional thickness of crust which otherwise would be required. This is

¹ Movement and distribution of moisture in soils. F. S. Harris and H. W. Turpin. Jour. Agr. Res., July 16, 1917, p. 117.

especially true of macadam and, as a consequence, both V-drain and Telford foundations have been employed frequently in connection with the macadam surface. It is less true of Portland-cement concrete only because its power of distributing pressure increases very rapidly with the depth and also may be greatly increased by properly arranged steel reinforcement which is usually cheaper to employ than any form of foundation.

Other types of road crust, such as blocks or setts, asphalt, and bituminous concrete, are intended only as wearing surfaces and in general must be supported on some form of artificial foundation. There are, of course, exceptional subgrade conditions where this is not true, as, for example, in the peninsular section of Florida, where the climate is mild and the soil consists essentially of sand which, when properly confined, has a relatively high bearing power under all weather conditions to which it is subjected. In this section brick roads have been constructed directly upon the sand subgrade with fairly satisfactory results.

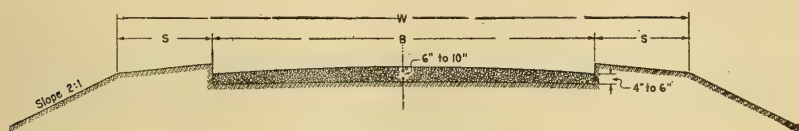
In this region where frost in the ground is unknown, it is necessary to provide only adequate bearing. The requirements of this nature should, however, receive careful consideration and types should be selected that can be repaired easily and successfully without loss of good material, in case the assumed bearing value of the soil is not developed in practice or decreases owing to deterioration of curbs, drying out of sand, or other strictly local causes.

Under the conditions usually prevailing neither the thickness of the road crust nor the combined depth of surfacing and foundation is adequate to prevent entirely the upheaval by frost, providing this is sufficiently extreme. The question of combating frost action still remains unsettled and exceedingly difficult of solution. The damage caused by it is very great in some cases and the economic aspect of the matter is involved. In general, it is not advisable to prepare elaborate and costly foundations to save comparatively cheap roads from slight damage; on the other hand, a considerable expense in foundation construction would be warranted if assurances existed that the effect would be to save an expensive surface from all damage. The entire question doubtless hangs on the reduction of soil moisture in the premises and the removal of free water at all times. To effect this the various methods of drainage discussed will serve largely if judiciously applied. The use of shoulder drains and ample provisions for relieving the subgrade and foundation near the surface of melted snow and ice in periods of alternate thawing and freezing will go a long way toward accomplishing the results desired. Generally in the northern part of the United States, the glaciated areas have well drained soils and frost action tends to be

local. Such sections as develop difficulties of this sort should be treated individually in order to get the best generally good results at lowest cost.

FOUNDATION TYPES.

The types of foundations in common use for country roads are (1) gravel, (2) crushed stone, (3) V-drains, constructed of field stones, (4) stone base, (5) Telford, and (6) Portland-cement concrete. Selected earth, sand, and cinders also have been used frequently to improve the supporting power of subgrades, but since the addition of such materials makes no essential difference in the general method of preparing the subgrade, they will not be considered as foundation materials. Road foundations have been constructed of brick, boards, corduroy, and many other special materials, and such construction is no doubt sometimes justified, although it is usually of a makeshift nature. In these cases the problem generally is concerned with employing local materials which may be secured at small cost and is one to be solved on the ground or after all the affecting conditions have been considered.



GRAVEL FOUNDATION

FIG. 14.

From what has been said it is evident that no very exact rules can be stated for determining what, if any, type of foundation should be selected as best for a general case. Foundation troubles are commonly local and peculiar and yield most readily to special treatment. The considerations that should influence the judgment in making a selection for a particular case are efficiency, and availability of materials, and cost of construction. It is possible to design foundations of any type mentioned above which would be efficient for any given condition of subgrade and type of road crust, but considerations of economy usually will serve to reduce the number of practicable types, for any particular case, to not more than two or three at most.

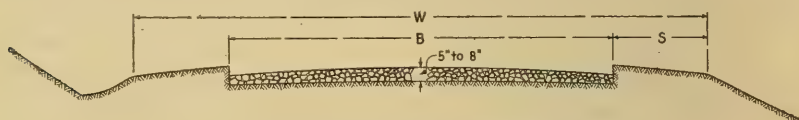
In general, gravel foundations are adapted to cases where the road crust also is to be of gravel or some other simple type, or where only slight additional stability is required for the subgrade to support concentrated loads on the road surface without being deformed. But, if the gravel possesses high cementing value, it may be used satisfactorily for foundations where crushed stone or concrete otherwise would be required. (Fig. 14.)

Crushed-stone foundations have been used for practically all types of road crusts where the subgrade conditions are favorable and a

good quality of stone is available. Such foundations usually are well adapted for road crusts of gravel, macadam, bituminous concrete, and, where the traffic is only moderate, for brick. (Fig. 15.)

The V-drain foundation is adapted to locations where field stones are readily available and where drainage of the subgrade is an essential function of the foundation.

Stone base is a modification of Telford where quarry spalls and broken stone are used, as in V-drains, but where the subgrade is shaped as for Telford. Such stone should be laid on the subgrade so as to bear firmly and not rock, but need not be broken, coursed, and wedged so carefully as Telford. It is finished with fine material,

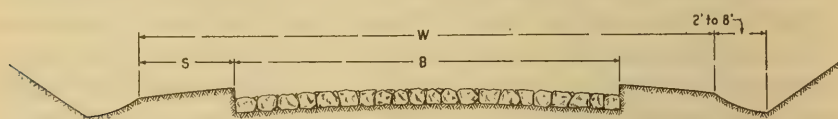


CRUSHED STONE FOUNDATION

FIG. 15.

like gravel, small stone, or sand, and rolled. Its use is similar to that of Telford.

Telford foundations have been used seldom except with macadam or gravel crusts. The reason for this is that the surface of a Telford foundation is irregular and such materials as gravel or crushed stone are well adapted to correcting the irregularities. Such advantage as Telford has over crushed stone foundations lies in the fact that since the individual stones are placed by hand larger stones are used that have greater bearing areas and give better distribution of pressure on the subgrade. This is an important consideration where



TELFORD FOUNDATION

FIG. 16.

the subgrade is not very stable and the necessary rolling of a crushed stone foundation might produce a wavy surface. (Fig. 16.)

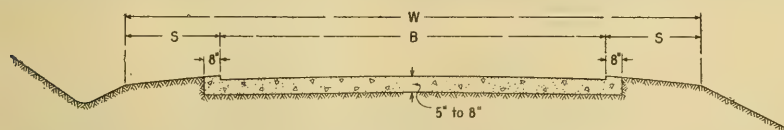
Concrete foundations are well adapted for use where the road crust consists of brick, asphalt, bituminous concrete, or any other material whose integrity and stability can be maintained only when extreme rigidity is supplied by the foundation. In addition to their rigidity, concrete foundations, when properly constructed, present fewer uncertainties due to lack of uniformity in materials and workmanship than any other type, and on that account are greatly to be preferred where the road crust is of an expensive type. Insurance against failure due to lack of uniformity in the subgrade can also, perhaps, best

be provided by means of a concrete foundation, and under extreme conditions of this sort concrete is practically the only satisfactory foundation material. (Fig. 17.)

DESIGN AND CONSTRUCTION.

No matter what type of foundation may be selected for a particular road or section of road it should, of course, be designed and constructed with a view to meeting adequately the conditions involved. Since these conditions vary greatly, sometimes even on the same project, it is manifestly impracticable to standardize either the design or construction of foundations except to a very limited extent. In the following discussion, therefore, no attempt will be made to do more than point out the limits of good design for each type of foundation and to describe, in a general way, what are believed to be the best methods of construction. Thus, unavoidably, much must be left to the judgment of those who design and superintend such work.

Practical experience and observation disclose that the best roads usually have a great variety of foundations. These may have been



CONCRETE FOUNDATION

FIG. 17.

laid at the time of original construction, or added to meet conditions that arise from season to season. For long distances the changes often occur as frequently as every few hundred feet. Rarely are constructed foundations now laid mile after mile, as was done formerly on the pikes of central Kentucky and elsewhere. The cost of such work is so great that the individual and local treatment has more generally been adopted by highway engineers.

GRADING AND PREPARING THE SUBGRADE.

The discussion on bearing power of different soils should be considered in connection with what is said here regarding the proper method of grading a road and preparing the subgrade. The table of bearing powers given on page 41 is based on the assumption that the roadbed and subgrade will be prepared in accordance with some such methods as those described below.

The shape of the subgrade varies somewhat with different types of foundations or road crusts, but this feature does not need to be especially considered here, because the recommended shape for the subgrade is shown for each type of foundation discussed. Where

the subgrade supports the road crust directly the cross section may be either flat or crowned to conform with the finished surface. The flat cross section generally is preferable, because when this shape is used the crown of the road will give a greater thickness of crust at the center where greater strength is desirable. The cross section of course may have any desired crown less than that of the finished surface.

The most important features to consider in forming a roadbed upon which any type of pavement is to be constructed are (1) adequate and effective drainage, (2) firmness and stability, and (3) uniformity in grade and cross section.

The question of drainage has been discussed separately in this bulletin and it is therefore unnecessary to give this feature further attention, except perhaps to emphasize its importance. This probably can be done best by calling attention to the fact that many earth roads have been converted from almost impassable stretches of mud into excellent driveways for all but extremely bad weather conditions by merely making proper provision for drainage with no other improvement whatever.

The second requirement, firmness and stability, can be secured only after effective drainage has been provided. Soils which absorb moisture readily can not always be drained properly during wet seasons, and should not be permitted to form a part of the roadbed except where full allowance for their reduced bearing power has been made in designing the foundation or road crust. While it is true that for some types of roads foundations are necessary only where soil conditions are unfavorable, it nevertheless is advisable to improve the unfavorable conditions so far as practicable by selecting the best available material for use in the subgrade, even when the very best type of foundation is to be employed. In order that the subgrade may be unyielding it is also necessary for the entire roadbed to be compacted thoroughly. In forming embankments the material should be spread in comparatively thin layers and each layer should be compacted by rolling or by properly directing traffic over it during construction. For this purpose a power roller weighing about 10 tons or a horse roller of less weight may be used. When the grading is substantially completed the subgrade in both excavation and embankment should be brought to its final shape by any suitable devices, and rolled.

Until recent years the preparation of subgrade usually has been done by hand with pick and shovel, and in localities where labor is cheap still may be done so; but quicker and less expensive methods may be used to advantage now. If the grade is to be flat, a drag of railroad iron often is satisfactory. Telford, V-drain, and trench foundations generally can be cut with plow and grading machine

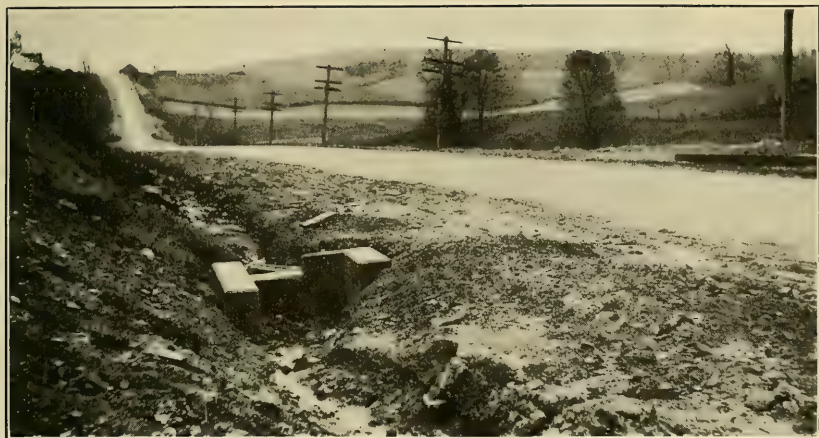
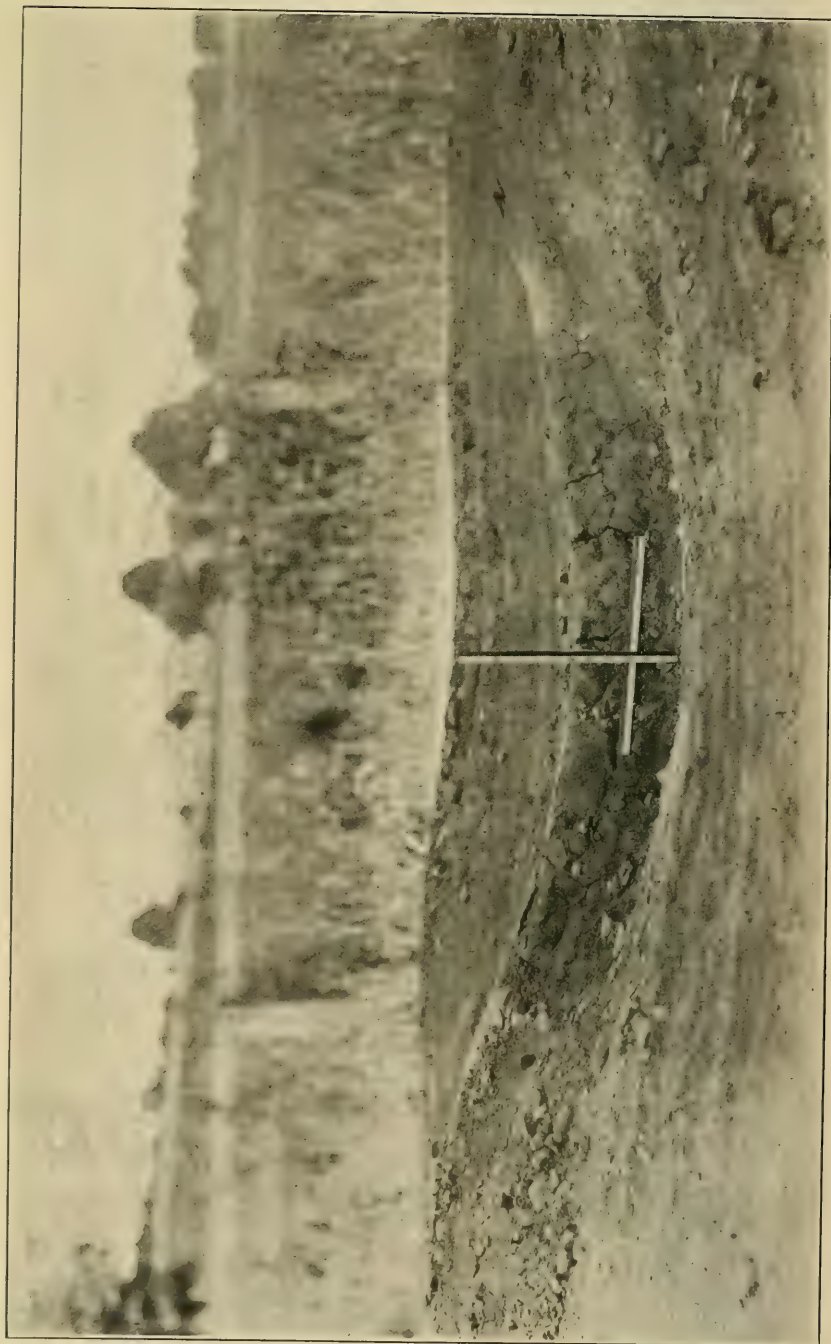


FIG. 1.—U HEAD WALL WITH PIPE CULVERT.



FIG. 2.—CONSTRUCTING V DRAIN.



SETTLEMENT OF PAVEMENT ABOVE PIPE CULVERT.

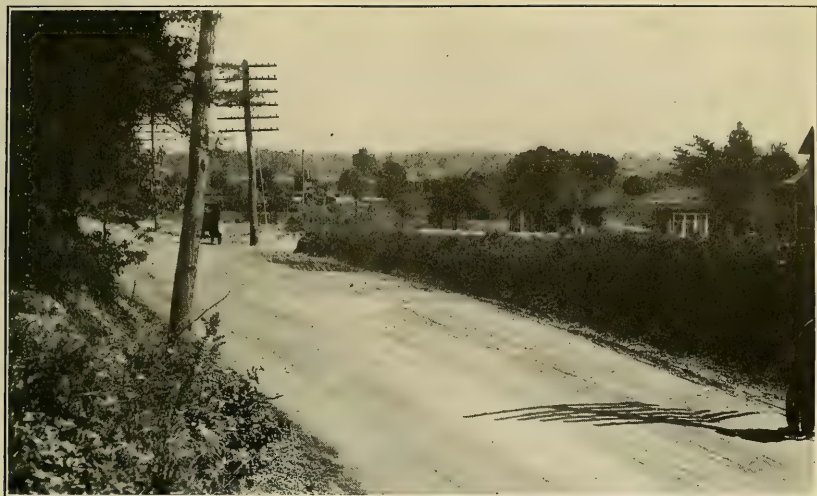


FIG. 1.—DEPRESSIONS OVER UNEVEN BASE.

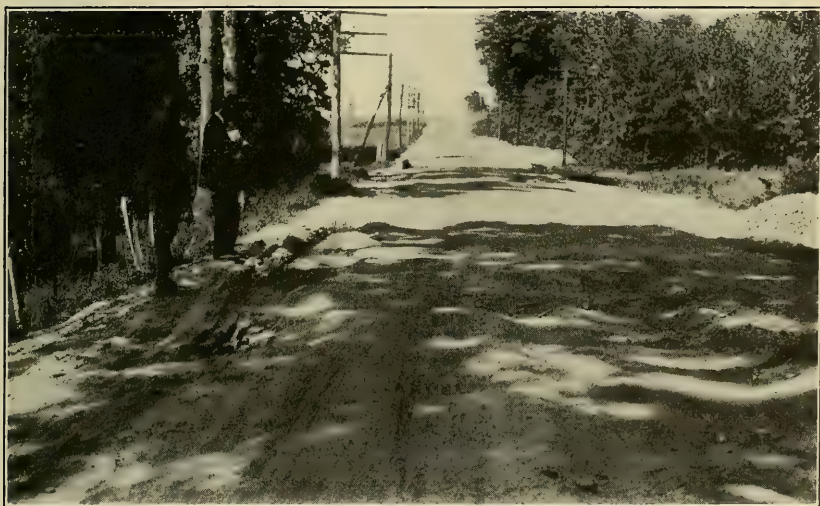


FIG. 2.—RUTS AND DEPRESSIONS OVER WEAK BASE.



FIG. 1.—LAYING FIELD-STONE BASE.



FIG. 2.—LAYING TELFORD BASE.

and finished with a light drag. Slips, wheelers, or Fresnoes may be used with entire success by skillful workmen, and if the heavy grading warrants its presence on the job a steam shovel in the hands of an expert operator can be used to do all but the finishing, which a light drag will do.

It is impracticable to supply detailed instructions as to the best methods for shaping and compacting all kinds of soil, because in many cases experienced judgment is the only safe guide. Where the soil composing the subgrade consists essentially of sand, for example, it may be necessary to wet the subgrade practically to saturation before it can be rolled satisfactorily, and in some cases pipe lines must be provided along the work to supply water for this purpose. On the other hand, clay soils can be rolled effectively only when comparatively dry, and when construction work is proceeding during wet seasons it may be necessary to provide additional facilities for draining the subgrade which would be wholly unnecessary if the work were being done under more favorable weather conditions. No matter what the circumstances of soil and weather may be, the subgrade, when completed, should conform closely in grade and cross section with the requirements of the plans and should present an even uniform surface. It also should be as firm and unyielding as the conditions will permit, because whatever the type of the foundation or the road crust, all loads passing over the surface must be supported ultimately by the subgrade, and unless this feature be sufficient the crust and foundation necessarily must fail.

Some of the most important details which require careful attention in preparing the subgrade, and are perhaps most frequently overlooked, are (1) back filling culvert trenches, (2) exclusion of vegetable matter from fills, (3) provision for draining any wet-weather springs that occur in the subgrade, and (4) the proper handling and use of materials contained in old road crusts which are to be worked into the new construction.

The back filling of culvert trenches is a detail requiring the very closest attention if subsequent settlement of the subgrade and road crust, over the trenches, is to be prevented. Most specifications governing this feature of the work make suitable provisions for having the back fills over all drainage structures properly tamped and compacted, but both engineers and contractors frequently have underestimated the cost of doing such work satisfactorily, and as a result there has been a strong tendency to permit and to do less compacting than the conditions require. The amount of compacting necessary varies, of course, with the character of the soil composing the back fill. Where the soil contains considerable sand or gravel and is moderately moist, it usually may be compacted best by placing the

back fill in layers not over 8 inches thick and thoroughly tamping each layer with a hand tamper.

The thickness of the successive layers and the weight and face of the tamper should be adjusted to produce the most uniform and solid compression reasonably possible. Common practice often is inadequate, sometimes the layers being made a full 8 inches thick and a light one-man tamper being used. On loose and friable soils a broad face is to be preferred, say 8 by 8 inches, and the weight may be raised to 50 pounds if double handles are provided and the work is done by two men.

Where the soil is essentially clay and the trench is deep, the back fill should be deposited preferably in courses and a tamper having a smaller face and weighing 10 to 15 pounds used.

If a clay or silt loam that readily breaks down in water is used, the trench should be filled at first to a depth of not more than 2 or 3 feet, the material being tamped thoroughly as above described, and the partial back fill then may be kept covered with water for several days until the material has become thoroughly saturated and has finished settling. Subsequent layers should be added and "puddled" until the trench is filled completely. Then it should be permitted to stand for several weeks, until the back fill has dried out, before the subgrade is prepared and the pavement constructed. Not infrequently it is cheaper to haul in gravel, or other material which may be compacted readily for use in back fills, rather than to replace clay according to the method above described. In some cases, where conditions were unusually bad, concrete has been used as a back-filling material. Plate VI shows a characteristic failure of a pavement over a culvert where the back fill had been poorly made.

The exclusion of vegetable matter from embankments is nearly always provided for in specifications covering road-improvement work, but in a great many cases the importance of this detail does not seem to be realized. As a rule, no especial harm results to a road from vegetable matter being placed in the slopes of embankments, because unequal settlement of the slopes would not necessarily injure the road surface. When sod and roots are placed in the subgrade, however, even in very small quantities, serious damage to the surface may result from the porosity caused by the eventual decay and shrinkage of the vegetable matter. Further, roots near the edges of the surface are very likely to live and grow, and the result is a weakening of subgrade on a line where the pavement is especially exposed to damage.

Wet-weather springs are not always in evidence at the time a road is being graded, and it is therefore important that the road be examined carefully during wet seasons in order to locate troubles of this kind. Such springs usually may be drained successfully by means of

ditches filled with stone and provided with suitable outlets or by the use of tiling. Methods of constructing drains of either kind are described in another part of this bulletin.

Where old road crusts or old base of broken stone, gravel, Telford, etc., are to be covered, the disposition of the old construction is important. A highway engineer can commit no greater error than to abandon or destroy an old and well-compacted road crust if it can be used as a foundation for a new road. If the new construction is to be gravel or macadam, the lesser irregularities of the old surface can be filled with gravel or fine stone after the old surface has been swept thoroughly. These patches should be well watered, covered with screenings, and rolled. On a base so prepared the new road can be built. If a bituminous top is to be placed directly on the old crust, lean bituminous concrete can be used to excellent advantage. The old surface should be swept thoroughly, the depressed areas painted with the same bitumen used in the mix, and the patches laid and raked with care. A 3 or 4 foot straightedge with a handhole is convenient in bringing the patch to a true surface uniform with the old. The entire series of patches should be rolled and allowed to set for at least 12 to 24 hours ahead of the topping.

If the new surface is to be wider than the old base or crust, it is more difficult to produce an even surface that will not settle at the edges. In many cases the only practicable disposition of the old crust is to loosen it and either waste the material or salvage it for the new top. Salvage methods usually are expensive.

It should be borne in mind that when the old crust is left undisturbed and simply evened up by the addition of new material, it is difficult to compact the new material as thoroughly as the old, and a tendency to uneven settlement of the subgrade will result. For this reason the greatest care should be used in making the preliminary patches. Plate VII shows the results of neglecting this detail.

In the premises the whole problem of making adequate use of old base is largely one of initial engineering. The grades should be laid with unusual care to take advantage of the old crusts, and where these are thin room should be left for necessary additional material.

Where practicable it is always well to have the grading and drainage structures for an improved road completed some time in advance of the pavement. This enables the roadbed to settle without doing any damage, and obviates the necessity for much of the tamping and compacting which otherwise would be necessary.

COST OF SUBGRADE PREPARATION.

The cost of preparing the subgrade of a road to receive the foundation or road crust depends to a very considerable extent on the degree

of care exercised in doing the rough grading, and to a less extent on the type of road crust or foundation which it is proposed to employ. The character of the soil composing the roadbed also may be an important consideration in estimating the cost of this work, especially if any considerable period of time elapses after the completion of the rough grading before the subgrade is prepared. Some soils remain loose indefinitely and are easily worked into proper shape, while others may become hard and compact in a very short time after being placed in a roadbed.

The following examples of road-improvement projects completed under the supervision of the Bureau of Public Roads have been selected to illustrate how the cost of subgrade preparation varies with the local conditions.

Example No. 1.—A macadam road in Montgomery County, Md.

Area surface, 47,456 square yards.

Character of soil, stiff clay.

Grading done with steam-shovel outfit and not very carefully finished.

Cost of preparing subgrade, 6.8 cents per square yard.

Work done with pick and shovels.

Cost includes necessary rolling.

Example No. 2.—Several sections of gravel road in Leflore County, Miss.:

Aggregate area surfaced, 189,535 square yards.

Character of soil, light loam.

Grading done with scrapers and fairly well finished.

Cost of preparing subgrade, approximately, 1.4 cents per square yard.

Work done with road grader and a limited amount of plowing required.

Cost includes necessary rolling.

Example No. 3.—A gravel road in Bexar County, Tex.

Area surfaced, 100,000 square yards.

Work consisted in scarifying and reshaping an old gravel road, and was done by means of a roller with scarifier and road grader.

Cost of preparing subgrade, 3.8 cents per square yard.

Cost includes picking out large stones that were turned up in scarifying, as well as all necessary rollings.

Example No. 4.—A concrete road in Licking and Muskingum Counties, Ohio:

Length of road, 24 miles; width of concrete surface, 16 feet; character of soil, stiff clay. The rough grading was done with steam-shovel equipment and scrapers, and the work was in progress during 1914 and 1915. During 1914 the subgrade was prepared almost immediately after the rough grading was completed, and the average cost of its preparation was approximately 3 cents per square yard. During 1915 the rough grading was completed several months in advance of the subgrade, and the average cost of preparing the subgrade was approximately 7.5 cents per square yard. This large difference in cost is attributable partly to the fact that several washing rains occurred between the time of completing the rough grading and the time of preparing the subgrade, and the work charged to subgrade preparations really included a considerable amount of rough grading made necessary by erosion of the roadbed.

GRAVEL FOUNDATIONS.

Gravel for use in road foundations should consist of sound, durable pebbles mixed with sufficient cementing material to bond the individual particles together firmly when the gravel is spread and rolled. Clay is the only cementing material carried by most gravels as they occur in nature, though there are a few deposits that contain other cementing agents, such as iron oxide, lime carbonate, etc. Foundations bonded with the latter materials are much more reliable than those in which the binder is composed essentially of clay. The ordinary gravel foundation with clay binder is used in general only where the wearing crust is to be of gravel also, while if the binder consists of some stable mineral cement, properly constructed gravel foundations may be employed with brick, bituminous concrete, or other highly improved types of road crusts.

It is customary to require that gravel used in foundations shall contain from 60 to 75 per cent, by weight, of pebbles ranging in size between such as will be just retained on a $\frac{1}{8}$ or $\frac{1}{4}$ inch screen and such as will just pass a $2\frac{1}{2}$ or 3 inch screen, and that the remainder shall consist of sand combined with some suitable cementing material. Where clay is the cementing material it should not comprise less than about 15 per cent nor more than about 20 per cent of the total weight. It is important that the gravel be evenly graded in size from fine to coarse and that the cementing material be uniformly distributed through the mass, because poor grading or poor distribution of the clay content evidently would tend to produce unequal density of the foundation.

It very often happens that, in order to be made suitable for use in a road foundation, natural gravel must be screened to remove a part of either the fine or coarse material so as to keep the different percentages within the limits mentioned above. It also is necessary sometimes to wash the gravel in order to remove excessive clay, but this process is expensive, and it generally is practicable to secure the desired results in some other way. When it is necessary to add clay it should be done as the gravel is placed by spreading a uniform layer of clay over each course of gravel and mixing the two together by harrowing.

If this is necessary, it must be done with the utmost care and great thoroughness. When it is realized that one load of clay to a hundred of gravel increases the clay content approximately 1 per cent, it is seen how difficult it may be to raise the clay a few per cent throughout an entire job. Almost always too much is added, and the distribution is exceedingly uneven. To obtain good results the clay should be as dry as possible, well pulverized, and distributed broadcast with shovels just as screenings are on a macadam road. This

clay should be shaken down dry with a harrow and in no case wetted and rolled until the whole mass is well mixed. If large quantities of clay are to be added it is better to place it in a layer between a first and second layer of the cleaner gravel. The foundation then can be wetted and rolled without preliminary harrowing, and the clay will not stick to the roller wheels. Wet clay in contact with the roller can almost never be mixed into the gravel, and endless trouble results from permitting it to occur.

Gravel foundations vary in compacted thickness from about 4 inches up to about 10 inches, depending on the condition of the subgrade and the character of the road crust, as well as somewhat on the quality of gravel used. The most usual thickness is from 5 to 7 inches. Except that where the road crust is to be of some highly improved type a thickness of about 8 inches generally is used. In general, foundations of more than about 5 inches in thickness must be constructed in two or more courses, as otherwise, unless the percentage of clay is unwarrantably high, it is almost impossible to produce a thorough bond between the particles by harrowing and rolling. Figure 14 shows a typical cross section for a gravel foundation upon which the limiting dimensions are indicated. This cross section shows the subgrade and foundation crowned to conform with the surface of the finished road, and probably is more frequently employed than any other form, but in some cases the subgrade is made flat, or even slightly "dished," and the whole crown of the road made up either in the foundation or the road crust. This latter arrangement provides for additional thickness of the pavement near the center where it usually is desirable to have the greatest strength. The principal precautions to observe in constructing gravel foundations may be described briefly and commented upon as follows:

1. The gravel should be delivered on the work in wagons or cars especially adapted to spreading each load uniformly over that part of the subgrade for which it is intended. Where loads are dumped in one spot and spread later with shovels, as is done frequently, it is almost impossible to secure uniform density of the foundation by subsequent harrowing and rolling. The spots where the loads are dumped will nearly always be more densely compacted than the areas in between and, as a result, uneven settlement soon will develop.

2. Where it is necessary to spread the gravel in more than one course the thickness of the different courses should be approximately the same, except that the first course may be made somewhat thicker than the others because, in general, a thicker layer of gravel may be compacted on the subgrade than when spread over another layer of gravel, although compacted. It usually is impracticable to have the finished thickness of any course greater than about 5 inches, and

in some cases 3 or 4 inches is as much as can be compacted satisfactorily at one time.

3. After each course of gravel is spread it should be harrowed thoroughly with a tooth harrow until the different sizes of particles and the cementing material are distributed thoroughly through the mass. Then it should be rolled repeatedly with a power roller weighing about 10 tons until the different particles are all well bonded together and the surface presents a smooth, uniform appearance. When completed, the surface of each course should appear firm and unyielding and should be such that no particles of gravel will be disturbed by men walking upon it.

4. Where it is necessary to add sand or clay to the gravel, in order to fill the voids, it should usually be done after each course is spread and before it is harrowed. But with some kinds of gravel and where certain types of road crust are to be used, it is permissible to add a limited amount of sand after the harrowing is all done and while the rolling is in progress, so as to secure a denser surface. This usually applies to the top course of the foundation when it is desirable to prevent bitumen, Portland-cement grout, or other similar material used in the surface crust from being wasted by penetrating into the foundation.

5. Where the binder consists of some material other than clay it may be desirable to sprinkle each course with water while it is being rolled, and even where clay is used as a binder a limited amount of sprinkling may be necessary in dry weather. The sprinkling always should be done uniformly and in such quantities as not to wash the fine material out from the gravel or to soften the subgrade.

6. When the foundation is complete it should be uniform in grade and cross section. If depressions occur under the roller, they should be corrected by adding gravel and continuing the rolling, and this should be kept up until the foundation is able to support the roller, moving back and forth over it, without appreciable waves being formed in the surface. When the rolling is complete the foundation is ready to receive the surface crust immediately.

COST OF GRAVEL FOUNDATIONS.

In estimating the cost of a gravel foundation it is necessary to consider:

1. The purchase price of the gravel it is proposed to use;
2. The cost of delivering the gravel on the work; and
3. The cost of spreading and compacting. The first two of these factors are evidently dependent to a very great extent on local conditions, and their influence on the cost of a given foundation can not be determined except by a study of the given conditions. The following

data are intended to serve only as an aid in making the necessary study:

A. A cubic yard of loose gravel ordinarily weighs between 2,700 and 3,300 pounds, the average weight being about 3,000 pounds.

B. Loose gravel will shrink from 12 to 15 per cent in volume when compacted in a road foundation. In determining the loose volume of gravel required for a given project it is customary to compute the compacted volume and add from 20 to 30 per cent to cover waste, shrinkage, and loss in handling.

C. The average cost of loading pit gravel by hand into wagons is about 20 cents per cubic yard. Where the amount of work to be done is sufficient to warrant the installation of a steam shovel or the construction of a special scaffold so that wheeled scrapers may be used for loading, the cost of this work usually may be reduced, the reduction sometimes amounting to 50 per cent or more.

D. The cost of screening gravel varies greatly according to the character of the pit-run material and the kind of screening equipment employed. Hand screening costs from 25 to 40 cents per cubic yard, while with a properly arranged mechanical screen the cost should not often exceed 15 or 20 cents per cubic yard.

E. The cost of hauling depends on the equipment used and the condition of the road over which the hauling is done. With teams at \$5 per day and the roads such that two tons may be hauled at a load, the average cost is about 25 cents per ton mile, or $37\frac{1}{2}$ per cubic-yard mile.

F. The cost of spreading gravel, on five road projects recently supervised by the Office of Public Roads and Rural Engineering, ranged from about 3 cents to about 8 cents per cubic yard. The average cost was about $6\frac{1}{2}$ cents per cubic yard and the average cost of labor was about 20 cents per hour. The wagons used in all cases were built so that they dumped directly upon the subgrade and were designed to spread the material to a considerable extent while it was being dumped.

G. The cost of rolling the gravel on the above five projects ranged from slightly less than one-half cent to about 1 cent per square yard. The average cost was about 0.6 of a cent per square yard. This included only the labor cost and if fuel for the roller and depreciation were considered the average cost probably would approximate $1\frac{1}{2}$ or 2 cents per square yard.

CRUSHED-STONE FOUNDATIONS.

Crushed-stone foundations have been made from practically all kinds of stone ordinarily available for such a purpose; and provided the stone be sound and durable, there is, in general, no occasion for limiting the varieties that may be so used. A moderately soft or brittle stone should prove equally as satisfactory for a foundation as one that is extremely hard and tough and usually would be much easier to crush, as well as to compact, than the hard, tough stone. The only requirements really essential are (1) that the stone shall possess sufficient resistance against crushing to withstand any load likely to come upon it, (2) that it will not be affected by the action of ground water, and (3) that it will bond together under the roller to form a dense, well compacted foundation. These requirements are based on the assumption that the foundation always will be protected from the

wearing action of traffic by some suitable surface crust, but these requirements would not be sufficient for cases where stone from the foundation eventually might form a part of the wearing surface.

In the case of water-bound macadam roads, for example, the so-called foundation course often is considered as a part of the wearing crust, because ultimately the stone of this course is expected to become the surface as the real wearing course is abated by traffic. Or it is expected that scarifying the road periodically when it is necessary to add new material will bring some of the lower course to the surface. This criticism would be applicable, of course, in less degree where it is purposed to maintain the road surface by bituminous treatments, or for water-bound macadam roads maintained properly with a distinct wearing course and with a foundation not essentially a part of the macadam crust.

The proper size of the stone for use in a crushed-stone foundation depends, first, on the depth of the foundation and, second, on the quality of the stone used. In order to have a locking or wedging effect under the roller it is essential that the stone be considerably less in longest dimension than the proposed thickness of the course. In general, no stone is used larger than 4 or $4\frac{1}{2}$ inches, and the maximum screen specified usually is 3 or $3\frac{1}{2}$ inches for a 6 or 8 inch foundation course. If the foundation is 4 inches, the screen usually is specified to have meshes $2\frac{1}{2}$ or 3 inches in diameter. Soft or thinly stratified rocks that are likely to break into tabular fragments are used quite generally in larger sizes than a hard, amorphous rock with cubical or rhombohedral cleavage. If much tabular rock comes through in the tailings, it should be re-run through a lower crusher to produce more fine stone, as such material usually is short on the low sizes. As in the case of gravel, it is customary to fix the size by specifying upper and lower limiting screens which the material shall pass and be retained upon, respectively, and by providing that the stone shall be well graded in size between the limits specified. Where the stone is hard and tough and does not crush to any extent under the roller it is impracticable to make the successive layers of the foundation more than 4 or 5 inches in compacted depth, because it is very difficult to compact a greater depth satisfactorily. In such cases the particles of stone preferably should be of such size that all will pass a screen having circular openings about $2\frac{1}{2}$ or 3 inches in diameter. If, on the other hand, the stone is moderately soft and brittle, the compacted depth of the foundation courses sometimes may be made as much as 5 or 6 inches and the upper limiting screen may have correspondingly larger openings. The lower limiting screen should, in general, be such that the amount of fine particles left in the screen product will be no more than sufficient to fill the voids and produce a dense, well compacted layer when the stone is

spread and rolled. Ordinarily a screen having circular openings from $\frac{1}{4}$ to $\frac{1}{2}$ inch in diameter should prove satisfactory for moderately brittle stone, while in other cases, where the stone is hard and tough, it may be permissible to omit the lower limiting screen altogether.

Not infrequently it is desirable to screen out certain sized particles from the product of the crusher for use in the road crust or for some other purpose, and in such cases only the larger sizes, with perhaps a part of the dust or screenings, are available for use in the foundation. With some varieties of stone this arrangement may not be objectionable because the large particles will wedge in together under the roller to form a fairly dense, compact foundation. But with other varieties, such as trap rock, for example, the large particles may not lock very readily and it may be necessary to fill the voids with either stone screenings, gravel, or coarse sand while the rolling is in progress, in order to aid in wedging the crushed stone particles firmly in place.

The compacted thickness of crushed-stone foundations varies in practice from a minimum of about 3 inches up to a maximum of about 9 or 10 inches. The small thickness of 3 inches should be used only for light-traffic roads where the subgrade conditions usually are favorable or where the road crust is capable of distributing the pressure under concentrated loads to a considerable extent, while the maximum thickness of 10 inches would be required seldom except where the surface crust is designed to withstand only the wear of traffic and the subgrade is poor. In the past the usual thickness has been about 6 inches, but under the heavy traffic which prevails at present on many of our improved roads the 6-inch foundation frequently has proved insufficient. This is shown by numerous partial or total failures of expensive road crusts, such as brick and bituminous concrete, due to foundation failure. It is believed that with average subgrade conditions and road crusts of the kinds above mentioned, the thickness of crushed-stone foundation should, in general, be considerably increased above the common practice of to-day.

The number of courses in which the stone should be spread and compacted depends on the depth of stone that can be compacted satisfactorily in one course, and, as explained above, this varies with the quality of the stone used. Ordinarily not more than two courses are necessary, unless the foundation is to be of unusual depth.

In some cases it has been found of advantage to use a crushed-stone foundation under a gravel wearing course. A recent design for heavy traffic where unusual speed of construction and immediate service were essential called for an 8-inch compacted quarry-run base and a 4-inch compacted gravel top. This made use of a relatively cheap but unsatisfactory macadam stone and a relatively expensive

but very quick bonding and satisfactory gravel. The soil was poor, being a micaceous clay, and the base was laid in two courses, with the first thoroughly harrowed to shake the finest to the bottom and close the foundation against the clay. No effort was made to close the top foundation course as the gravel topping served adequately to do this.

Figure 15 shows a typical cross section for a crushed-stone foundation and indicates the limiting dimensions used in good practice.

The proper manner of spreading and compacting the stone probably can best be described by stating certain precautions it is necessary to observe in order to secure satisfactory results. In doing this it will be necessary to repeat several of the precautions already mentioned as being applicable to gravel foundations, because the two types of construction are very similar in many respects. In fact, where the gravel used is such as to compact readily without the presence of clay the construction methods are practically the same as when crushed stone is used.

1. The first precaution in constructing a crushed-stone or any other type of foundation, of course, is to see that the subgrade is well prepared of good material and that it is firm at the time the stone is spread.

2. The stone should be delivered in vehicles adapted to spreading it out in a uniform layer to the required loose depth. If such vehicles are not available, the stone should be dumped on platforms and spread to the required depth with hand shovels. This requirement is of especial importance because it is practically impossible to secure a uniformly compacted foundation unless some such method is followed. Where whole loads are dumped on successive spots of the subgrade and spread by merely raking off the tops of the piles thus formed, a dense core will be formed where each load is dumped and the area between cores will be much less dense. When the layer of stone is rolled, the roller will tend to ride on the cores with the evident result that the foundation will not be uniformly compacted and while its appearance may be satisfactory when first completed, lack of uniform density is almost certain to result later in irregularities, and these will continue to occur long after completion of the top or wearing course.

3. If in hauling and spreading the stone, the fine and coarse particles become more or less separated, as frequently is the case, each layer of the foundation should be harrowed with a tooth harrow until the different sized particles are distributed uniformly throughout the mass. When moderate care is used in handling the stone harrowing should not generally be necessary, though with some varieties of stone there seems to be a strong tendency for the dust and fine particles to become segregated while the material is being loaded into vehicles and in such cases harrowing may be very desirable.

4. After each layer of the stone is spread, and harrowed if necessary, it should be rolled with a power roller weighing about 10 tons, until it is thoroughly and uniformly compacted. The rolling should begin preferably at the edges of the road and progress toward the center, and should continue until no appreciable settlement is caused by additional rolling.

5. In general, the voids in the top layer of the foundation should be filled by spreading coarse sand or stone screenings over this layer while the rolling is in progress. With some varieties of rather brittle stone the voids may be filled

fairly well by particles of stone crushing under the roller and in such cases the addition of sand or screenings may not be necessary. The character of the road crust also should be considered in deciding this point.

6. In order to lock the particles of stone together satisfactorily it frequently is necessary to sprinkle a moderate amount of water over each layer of the foundation while the rolling is in progress. This is especially true of limestone where screenings are added after the stone is spread. In all cases where water is used it is merely to flush the fine chips and dust into the interstices and by no means to produce a grouted surface, and it should be applied gently and in such quantities as not to saturate the subgrade and should be done only on sections of the foundations where rolling is in progress.

COST OF CRUSHED-STONE FOUNDATIONS.

The cost of constructing a crushed-stone foundation, after the stone has been delivered on the work, usually can be estimated with a fair degree of accuracy when the conditions affecting the work are understood. If the stone is hauled out in suitable dump wagons and the price of labor is about 20 cents per hour, the spreading can be done at an average total cost of from 6 to 8 cents per cubic yard. Where the stone is dumped on boards and spread by hand this cost ordinarily will be just about doubled.

The cost of rolling varies with the quality of the stone used. If a hard limestone or trap is used, about 100 cubic yards can be compacted per 10-hour day with a 10-ton roller, while with sandstone or soft limestone the quantity compacted per 10-hour day may be as much as 150 or 175 cubic yards. Assuming the loose depth of the foundation at 9 inches and the cost per day of a roller, including labor, fuel, and depreciation, at \$12, the total cost of rolling would average from 2 to 3 cents per square yard. The cost of spreading and rolling combined would average from $3\frac{1}{2}$ to 5 cents per square yard.

The cost of quarrying and crushing varies with the character of the stone, the layout of the quarry, and the equipment employed. Some of the largest producers of crushed limestone market their product at about 50 cents per ton, or 65 cents per cubic yard, while in other cases, where the quarry face is shallow and the plant is small, the actual cost of quarrying and crushing sometimes is more than \$1 per cubic yard. The following record is of a limestone quarry in Loudon County, Tenn., operated under the supervision of the Bureau of Public Roads in connection with a single road improvement project, may be of assistance in estimating costs for similar work in other localities. The quarry had been faced up, but required heavy stripping, and the presence of numerous clay seams made drilling and blasting expensive. The stone is a dark-blue, tough limestone, very similar in appearance to Knoxville dolomite. The depth of quarry face was from 12 to 18 feet. Blasting was done

with 40 per cent dynamite, fired by means of batteries, and the rock was hauled to the charging platform in dump carts. A 25-horsepower engine and a No. 4½ crusher were used. The record output was 183¾ cubic yards in one day of 14 hours. The bins were of 70 cubic yards capacity with three subdivisions. The scale of wages was:

Superintendent	per day--	\$4. 50
Timekeeper	do--	2. 00
Quarry foreman	per hour--	. 20
Drill runners	do--	{ . 17½
		{ . 20
Crusher feeders	do--	. 17½
Crusher engineman	do--	. 25
Powder man	do--	. 16
Unskilled labor	do--	. 15
Water boy	do--	{ . 05
		{ . 07½
Cart and driver	do--	. 25

The items of cost were:

Labor:

Superintendence	\$128. 10
Stripping	219. 03
Drilling and blasting	412. 57
Sledging	798. 31
Hauling to and charging crusher	1, 306. 38
Crushing and screening	326. 74
Repairs to crusher	42. 80
Sharpening steel and small tools	214. 03

Materials:

Coal	89. 45
Oil	11. 20
Dynamite, caps, and fuse	261. 10
Repairs to crusher	48. 70
Small tools	64. 70

Finance:

Interest on investment, depreciation, etc.	475. 85
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Total	4, 398. 46
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Total stone quarried and crushed	cubic yards-- 4, 932. 3
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Cost per cubic yard for quarrying and crushing	\$0. 80
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The cost of quarrying and crushing will average at least 25 per cent higher for trap or granite than for limestone where the quarry conditions are similar.

The largest producers of crushed trap seldom can afford to sell their product at less than about 65 cents per ton or 85 cents per cubic yard, f. o. b. plant, and where the stone is quarried in small quantities the actual cost may greatly exceed those figures. For example, nine small trap and granite quarries in the State of Maine, operated

under the supervision of the Bureau of Public Roads, showed a total average cost for crushing and quarrying of about \$1.25 per cubic yard. The total quantity of crushed stone taken from the nine quarries was about 55,000 cubic yards.

V-DRAIN FOUNDATIONS.

The proper method of constructing V-drain foundations has already been discussed under "Drainage" on page 37. A typical cross section for such a foundation is shown in figure 13 and the ordinary method of construction is illustrated in Plate V.

TELFORD FOUNDATIONS.

The stone used in constructing Telford foundations should be sound and tough, so that when wedged into the foundation individual pieces of the stone will not crack or be loosened when rolled or when irregularities are broken off with a hammer. Since the relation between the different particles of stone composing a Telford foundation necessarily must be almost wholly mechanical and its rigidity, therefore, depend on the interlocking of slight irregularities in adjacent stone surfaces, it is evident that if the stone lacks in soundness or toughness, the individual particles might be loosened easily by the shearing off of these irregularities, and whatever load came upon stones so loosened would be transmitted almost undistributed, and therefore unreduced, to the subgrade. Such varieties of stone as soft limestone, brittle sandstone, and decayed granite could not, as a rule, be used satisfactorily in a Telford foundation, though, under favorable subgrade conditions, they might be used advantageously in a crushed-stone foundation.

Satisfactory Telford foundations may be constructed of either quarried or field stone. But, in general, quarried stone is to be preferred, not only because it usually is tougher and more durable, but because it is easier to obtain a good mechanical bond between fresh stone surfaces than between those which have been exposed to the weather for some time and worn more or less smooth. It is also easier to secure a firm uniform bearing for pieces of stone having approximately plane surfaces, than where the surfaces are rounded, as is the case with field stone.

The dimensions individual stones should have need not be fixed very definitely, except that the depth should be equal to the depth of the foundation. In general, the length should not be less than the depth nor greater than about twice the depth. If the length is less than the depth the stone will not be in a stable position, while if the length is greater than about twice the depth it is difficult to insure a uniform bearing. The minimum allowable width depends somewhat on the quality of the stone used as well as on the dimensions. Where an exceptionally hard and tough variety of stone is

used it is permissible sometimes to make the minimum width as low as $1\frac{1}{2}$ inches, but for most conditions this minimum should be preferably not less than about 3 or 4 inches. The maximum allowable width is controlled by much the same considerations as the maximum length, and in general, should not be greater than about 9 or 10 inches.

CROSS SECTION.

The cross section of a Telford foundation usually is shaped in one of three ways: (1) The subgrade may be crowned to conform with the surface of the finished road and the depth of Telford made uniform for all parts of the section; (2) the subgrade may be flat and the depth of the Telford increased from sides to center so as to give the required crown; (3) both subgrade and Telford may be given a flat cross section and the required crown secured by increasing the depth of the surface crust from sides to center.

The first method, which is the one most commonly employed at present, has the advantages that the stones do not need to be sorted so as to secure a uniformly varying depth and that any tendency of the subgrade to settle irregularly will be counterbalanced in a measure by the arch action of the tightly wedged Telford.

The second method was the one employed originally and, while it is more expensive than the first, the extra depth it affords at the center may be of especial advantage where the subgrade consists of soil that is hard to drain. If the side ditches are not sufficiently deep to lower the ground water level below the frost line at the center of the road, an additional depth of Telford at this point evidently would decrease the likelihood of heaving due to freezing of the subgrade.

The third method affords practically the same safeguard against frost as the second, but is subject to the objection that the slightest irregular settlement of the subgrade will weaken, rather than strengthen, the mechanical bond between the different Telford stones and thus will increase the tendency for irregularities to develop.

Figure 16 shows a typical cross section for a Telford foundation, and Plate VIII is a photograph illustrating the method of construction.

DEPTH.

The depth of Telford foundations varies in common practice from 6 to 8 inches. Where subgrade conditions are extremely unfavorable it may be advisable to increase the depth above 8 inches, but under no ordinary circumstances should a depth less than about 6 inches be employed, because when the depth is less than this it is hardly practicable to bond the individual stones together securely by wedging and rolling.

CONSTRUCTION.

In constructing a Telford foundation the stones are set by hand on the prepared subgrade so as to break joints roughly in the courses, which should be approximately straight across the road. Each stone should be placed with its long dimension in the direction of the courses and should be bedded evenly on the subgrade. The stones should be set together as closely as practicable and should be wedged firmly in place by means of spalls as the setting proceeds.

Ordinarily, the Telford stone is hauled out and distributed on the subgrade ahead of the men who do the setting, the individual pieces being of such size that they may be handled readily by one man. Then, as the stone is needed for use, it is broken to the required size with sledge hammers and placed in the foundation as above described. Under average conditions two laborers to each stone setter are required to select and carry the stone to where it is needed, and to assist in wedging up the foundation with spalls.

As the wedging proceeds all projections of more than about 1 inch above the intended surface of the foundation should be broken off with hammers and the spalls thus obtained used as wedges. When the laying and wedging are complete, the surface of the foundation should present a fairly uniform appearance and should be free from open or loose joints.

As soon as practicable after the stone is placed the foundation should be rolled with a power roller weighing about 10 tons. If depressions develop under the roller that indicate failure of stone or soft subgrade, they should be corrected by taking up and relaying the affected portions, and the rolling and relaying should continue until no such depressions occur. If the road crust is such as to require a smooth foundation, the irregularities of the Telford may be overcome by spreading a layer of coarse sand or stone screening over the surface while the rolling is in progress. In the past, however, Telford foundations usually have not been employed except in connection with macadam or gravel road crusts, and with these the small irregularities of the Telford surface are not objectionable.

COST OF TELFORD FOUNDATIONS.

The cost of setting Telford varies with the character of stone used. Where the stone is laminated, for example, the individual pieces usually will be such as to fit snugly together and comparatively little wedging with spalls will be necessary. Thin-bedded limestone lays especially well in Telford construction. But if the stone is unstratified, it will break into irregular pieces, and the work of breaking off projections and wedging up the foundation will be increased correspondingly. A study of available data shows that where the stone is

delivered on the work in sizes suitable for handling by one man it can be broken and placed in a foundation of ordinary depth at the rate of from 1 to 3 square yards per laborer per hour. Assuming labor at 20 cents per hour and making a reasonable allowance for overhead charges, the cost of setting and wedging an ordinary Telford foundation may be estimated at from 10 to 25 cents per square yard; the variation being controlled by the character of the stone.

The cost of quarrying and hauling has been discussed in connection with crushed stone and gravel foundations, and it is evident from those discussions that no definite rules for estimating these items can be stated. In localities where Telford foundations have been used extensively the cost of quarrying generally varies between 40 cents and 75 cents per cubic yard, according to the character of the stone and the methods employed, and the contract price for the foundation is between 50 cents and 90 cents per square yard.

CONCRETE FOUNDATIONS.

At present concrete foundations are constructed almost exclusively of Portland cement concrete, and are used generally in connection with such types of road crusts as granite block, vitrified brick, wood block, asphalt, and bituminous concrete. The advantages possessed by concrete foundations for these types are:

1. Properly prepared concrete is more uniformly reliable in distributing the pressure due to concentrated loads than any other material of which road foundations are ordinarily constructed. Concrete foundations are to be preferred therefore, for expensive road crusts such as those mentioned above, which might be damaged seriously by settlement of the foundation.

2. For all practical purposes as foundations concrete is impervious to water and prevents the surface crust from being damaged by the action of ground water, or surface water from percolating through to the subgrade, where either of these conditions otherwise might occur.

3. In case of slightly irregular settlement of the subgrade a concrete foundation may be sufficiently strong to act as a bridge over depressions which, with other types of foundations, would cause irregularities to develop in the road surface. The extent to which a concrete foundation affords these advantages is controlled by the design of the foundation, the selection of the concrete materials, and the care exercised in construction. Each of these features will be discussed briefly.

DESIGN.

Figure 17 shows a typical cross section for a concrete foundation and indicates the limiting dimensions ordinarily used in good practice. A lower minimum depth than 5 inches at the center is used sometimes, but hardly can be justified by experience, except where the surface crust is designed to aid materially in distributing the pressure due to concentrated loads. Plate IX shows an example of failure where a sand-filled brick pavement was constructed on a 4-inch

concrete foundation. An inspection after failure showed that the foundation of this road was made of rather poor grade concrete, and was not uniformly of the required depth, but the completeness of the failure would seem to indicate that even full 4 inches of good concrete hardly would have been sufficient. In this case the subgrade conditions were fair and the road had held up under light traffic for about one year, when failure was caused by a few trips of a loaded motor truck.

The maximum depth of 8 inches is sufficient for all ordinary subgrade and traffic conditions, provided a good quality of concrete is used, and in most cases a depth of 6 or 7 inches has proved entirely sufficient.

Though the strength of a concrete slab increases rapidly with an increase in depth, the conditions affecting the concrete road foundations are so involved that no data now available furnish reasons for a definite conclusion as to the rate of increase. When the probable effects of an increase of depth are all considered, such as greater strength as a simple beam, extra dead-weight to act against frost, additional resistance to cracking under changes of temperature and moisture, additional strength to resist impact, and the lower percentage of scant thickness produced locally by the unavoidable irregularities of subgrade, it is probable that a 6-inch slab foundation will give at least twice the effective service that a 4-inch slab will give.

If it be deemed advisable to employ a greater depth than 6 inches, it usually is permissible to decrease the depth from the center toward the edges. This is done by flattening the crown of the subgrade.

CURBS.

The types of road crust ordinarily requiring concrete foundations also usually require curbs of some kind to protect the marginal portions of the crust from disintegrating under traffic. The curbs may be made of either concrete or stone, and, for country roads, are designed to come flush with the road surface. Stone curbs should have a depth of from 12 to 18 inches, according to the depth of the frost line, and should be set before the foundation is laid. Concrete curbs may be constructed either separately or in combination with the foundation. In the former case they should have a cross section similar to stone curbs and should be constructed in place ahead of the foundation, while in the latter they may be simply flanges on the edges of the foundation, formed of rich concrete poured before the concrete of the foundation has taken its initial set. The proper thickness for both stone and concrete curbs varies somewhat with the conditions involved, but 6 inches is the thickness employed most commonly. Four inches is the minimum likely to prove satisfactory

under even the most favorable circumstances, while 8 inches is sufficient for the worst conditions, except in the case of stone curbs where the stone used is not of very good quality. In the latter case a thickness of as much as 12 inches has been employed.

STEEL REINFORCEMENT.

In a few instances concrete foundations have been reinforced with steel in order to secure the required strength with less depth. But, in general, the use of steel reinforcement has been confined to anchor rods for tying flange curbs on to the foundation. For this purpose one-half-inch rods spaced about 18 inches apart should be sufficient. The rods should extend about 1 foot back into the foundation and should be bent so as to project up into the curb near its inner face.

MATERIALS.

The materials composing Portland-cement concrete are: (1) Portland cement, (2) sand, (3) gravel, crushed stone, or crushed slag, and (4) water. To secure high-grade concrete it is necessary that each of the constituent materials shall possess certain definite qualities. Inferiority in the quality of a single constituent may easily be responsible for complete failure of the concrete in which it is used, and can not be overcome by the relative excellence of the other constituents. While the cement and sand are the two materials most frequently responsible for failures, the coarse aggregate usually composes the bulk of the concrete, and if it is defective a corresponding weakness necessarily must be apparent in the concrete.

In selecting materials for concrete availability is, of course, a very important consideration, but preference for local materials should be exercised only in so far as it can be controlled by such requirements regarding the quality of the materials as are known to have produced satisfactory results. Wherever any doubt exists as to the suitability of some particular material proposed for use in the concrete it should be subjected to such tests as will determine the points in question before its use is permitted. The following brief discussions of the different concrete materials should serve at least as a partial guide in making proper selections.

Cement.—Portland cement is manufactured in nearly every section of the country, and most plants are equipped to turn out a satisfactory product. But the facts that poor cement sometimes may be produced by the most carefully operated plants, and that good cement is damaged easily by age or exposure make it advisable to subject the cement to very careful investigation before it is used. Suitable specifications for Portland cement have been issued by the United States Bureau of Standards in their Circular No. 33 and by the

American Society for Testing Materials. Since copies of these specifications may be obtained readily the detail requirements which they contain will not be repeated here.

Sand.—The strength of cement mortar depends almost as much on the quality of the sand used as on the quality of the cement. The requirements to which it should conform in order to produce a strong mortar are: (1) It should be clean. Sand which contains more than about 3 per cent by weight of foreign materials, such as clay or loam, is unsuitable for use in concrete. (2) It should be absolutely free from acids. Not infrequently sand banks will become impregnated with acids from decayed vegetable matter which seriously affect the strength of cement, and in order to provide insurance against the presence in the sand of such acids or other similar deleterious matter it is good practice to provide for testing mortar briquettes made of the sand and cement it is proposed to use in the work. (3) The sand particles should be graded in size so that the percentage of voids will be comparatively low, though a sand in which all the particles are moderately coarse usually is considered preferable to one in which very fine particles predominate.

Because of the importance of the sand and the practical difficulties in grading it in large quantities it is customary to specify certain general physical tests, usually such as may be made with a set of hand screens, and in addition requiring that it shall develop a strength equal to or bearing a specified relation to a definite standard. A satisfactory specification is to require the dry sand to pass a one-quarter-inch mesh, that not more than 20 per cent by weight shall pass a sieve having 50 meshes to the linear inch nor more than 5 per cent shall pass one having 100 meshes per inch. Sometimes it is specified that not more than 60 per cent nor less than 20 per cent shall be retained on a sieve having 20 meshes per inch. Comparison with the mortar made with Standard Ottawa sand and the same cement in the same proportions and under like conditions is generally specified, to the end that the sand as it runs shall develop at least as good results as the standard sand. For detailed specifications see United States Department of Agriculture Bulletin No. 249, Portland Cement Concrete Pavements for Country Roads.

Coarse aggregate.—Coarse aggregate for concrete to be used in road foundations may consist of crushed stone, crushed slag, or gravel. It is claimed that coarse aggregate consisting of angular-shaped particles, such as crushed stone or slag, possesses some advantages over gravel because of the better bond secured between the individual particles and the mortar of the concrete. This claim seems at least partially justified by the fact that foundations constructed of gravel concrete usually have cracked somewhat worse than when the other materials have been used as coarse aggregate,

but it is doubtful if the difference would warrant any very expensive discrimination against gravel so far as concrete foundations are concerned.

No matter what kind of coarse aggregate is used it should consist of sound particles of at least moderate toughness, and should be practically free from clay, loam, and other foreign matter. In general, the specification for coarse aggregate should be drawn with a view to securing the best material available, and not merely to exclude material of a known unsatisfactory character.

The difficulties experienced in securing satisfactory coarse aggregate frequently are due to a lack of facilities for preparing the natural materials available locally, rather than to any lack of natural materials. There are few gravel pits, for example, which furnish gravel suitable for use as concrete aggregate without washing, and this process, to be carried on economically, requires a rather expensive plant. It is necessary also that stone be quarried, and slag must be selected carefully; and, moreover, both must be crushed before they are suitable for use as concrete aggregate.

The size of the particles composing the coarse aggregate is an important consideration and usually is fixed by specifying upper and lower limiting screens which the coarse aggregate shall pass and be retained upon respectively. Experience has shown that for concrete foundations the largest particles of coarse aggregate should be such as just pass a screen having circular openings equal in diameter to not more than one-third or less than about one-fourth the depth of the foundation. The lower limiting screen should have openings of from one-quarter to one-half inch in diameter according to the amount of fine particles present in the unscreened material. It is very desirable that the particles be graded in size between the upper and lower limits specified so as to secure a dense mass. This perhaps may be best assured by providing that not less than a certain percentage of the coarse aggregate shall pass and not less than a certain percentage be retained upon a properly selected intermediate screen.

Water.—The water used in mixing concrete should be reasonably clear and practically free from alkalis, acids, vegetable matter, or other injurious materials. Ordinarily very little difficulty is experienced in obtaining suitable water.

PROPORTIONING.

The proportion in which the materials should be mixed for concrete to be used in road foundations depends, theoretically, upon the percentages of voids in the sand and coarse aggregate. In theory, the amount of cement should be just sufficient to fill the voids in the sand and coat the individual sand grains with cement paste, and the

amount of sand and cement mortar should be just sufficient to fill the voids in the coarse aggregate and coat the individual particles of aggregate with mortar. In practice, the percentage of voids varies considerably, especially in the coarse aggregate, even with materials from the same source, and it is impracticable to vary the proportions to correspond with the voids. It is customary, therefore, to fix a definite proportion, by bulk, in which the materials shall be mixed, without further reference to the voids than to consider the general nature of the aggregates it is purposed to use. This arrangement works out satisfactorily, provided the proportion be chosen intelligently.

The percentage of voids in concrete materials average about as follows:

	Per cent.
Sand	30 to 40
Gravel.....	30 to 45
Crushed stone.....	35 to 50
Crushed slag.....	40 to 50

The proportions most commonly used for road foundations are, where the coarse aggregate consists of gravel, 1 part of cement, $2\frac{1}{2}$ parts of sand, and 5 parts of gravel, or 1 part of cement, 3 parts of sand, and 6 parts of gravel; where crushed stone or slag is used as coarse aggregate, 1 part of cement, 3 parts of sand, and 5 to 6 parts of coarse aggregate. Sometimes, when it is purposed to use especially well graded coarse aggregate and great strength for the concrete is not deemed necessary, it may be permissible to specify a proportion of 1:3:7, but in general, no concrete leaner than 1:3:6 should be used in road foundations without first making a series of tests to demonstrate whether satisfactory results may be secured by using a smaller proportion of mortar.

CONSISTENCY.

The two considerations that should determine the consistency of freshly mixed concrete to be used in road foundations are: (1) It should be sufficiently wet to be spread, shaped, and compacted with facility. (2) It must not be mixed so thin as to lose its crown or to flow on grades after it is struck off and shaped. It has been claimed frequently that a rather dry mixture, provided it is properly tamped, makes stronger concrete than wet mixture, and this claim no doubt is partly true. But the additional tamping necessary to secure a dense mass, together with the extra difficulties involved in striking off and shaping the dry mixture, add considerably to the cost of doing the work, and it is doubtful if the advantage gained is commensurate with this extra cost. When the concrete will hold a crown of at least one-quarter inch to the foot immediately after it is placed

in the foundation, struck off and shaped, it is not at all likely to be seriously defective in strength on account of the mixture having been too wet. The consistency necessary to meet this requirement frequently is described in specifications as "jellylike."

The amount of water required to produce a jellylike consistency varies with the condition of the aggregates as well as with the amount of mixing a batch of concrete receives. In general, the better the concrete is mixed the less water is required, and the amount of water used for each batch should be just sufficient to produce the desired consistency when the batch has been mixed thoroughly. This amount can be best ascertained by trial, and frequently must be modified from time to time as the work progresses.

CONSTRUCTION.

The different steps involved in constructing a concrete foundation should proceed in the following order: (1) The subgrade should be prepared in accordance with the method already described. (2) The materials should be hauled out and deposited on the subgrade. (3) The concrete should be mixed, placed, and properly finished. (4) The foundation should be kept closed to all traffic for about 10 days, and protected from too rapid drying out by a covering of earth or other suitable material. (5) The earth covering is removed and the foundation is ready to receive the pavement.

Curbs are not mentioned above, because the order in which they are constructed depends on the type employed. If the curbs are separate from the foundation they should be constructed while the subgrade is being prepared and before the foundation materials are hauled out. If constructed as flanges on the foundation, the outside forms should be set as the subgrade is prepared and then side forms while the concrete is being placed. Forms may consist of either 2½-inch wooden boards or of steel channels, though the steel is to be preferred. The forms should, of course, be set true to line and grade and should be well braced so as to resist springing out of shape when concrete is placed against them.

The materials may be hauled out in any one of several different ways. From the standpoint of economy alone, teams ordinarily would be used for small quantities of work and moderately short hauls, tractors or motor trucks for good roads and long hauls, and industrial railways where the roads are poor and the quantity of work to be done is sufficient to warrant the purchase of the necessary equipment. From a standpoint of excellence, the industrial railway is preferable to the other methods, because hauling over an industrial railway would not disturb the prepared subgrade in any way, while with the other methods it usually is impracticable to prevent the sub-

grade from being more or less damaged. Where hauling over the prepared subgrade is permitted it always tends to produce a lack of uniformity by increasing the degree of compactness of the parts traversed, and this may result easily in unequal settlement with consequent cracking of the foundation and road crust.

If the locality of the construction is one where rains are heavy and frequent, or in a season having such rains, judgment should be exercised in placing the materials on the subgrade very far in advance of the time they are needed for use, because under such conditions the subgrade may become saturated under the material piles and not dry out before the concrete is placed.

According to present practice concrete for road foundations is almost invariably mixed in a machine mixer. Hand mixing can be afforded only where the work to be done is inconsiderable and rarely produces as uniform concrete as machine mixing. In this discussion, therefore, it will be assumed that a machine mixer is employed in all cases. To accomplish satisfactory work under the conditions met ordinarily in foundation construction the concrete mixer should possess the following features: (1) It should be of the batch type, so that uniform proportioning of the material may be assured; (2) it should be fitted with a traction attachment so that it may be moved along the road under its own power as the work progresses; (3) it should include a device for distributing the concrete. This device may consist of a boom with a bucket traveler, a chute, or a revolving tube. The boom and bucket is to be preferred generally because it enables a greater area of foundation to be placed from one position of the mixer than either of the other devices, and consequently machines so equipped require less moving than others.

Sometimes the concrete is mixed in a stationary mixer and hauled to its place in the foundation, but this method is objectionable because it permits a separation of the component materials to take place between the time of mixing and the time of depositing. If a uniformly dense concrete is to be produced it must be deposited in the foundation immediately after it is mixed. Failure to secure uniform density impairs the strength of the concrete, and, in extreme cases, may cause cracks to develop in the foundation, thus greatly lessening its power of distributing stresses due to concentrated loads.

The principal precautions essential to observe in mixing and placing concrete in a road foundation are to see—

1. That the amount and time of mixing is sufficient to secure a thorough distribution of the different materials through the mass and complete hydration of the cement. Tests have shown that increasing the time a batch of concrete remains in the revolving drum of a mixer, within reasonable limits, has very much the same effect as increasing the proportion of cement. The efficiency with which mixers work, as expressed in the strength of concrete, varies



ABOVE: SAND-FILLED BRICK ON CONCRETE FOUNDATION. BELOW: FAILURE OF SAND-FILLED BRICK ON 4-INCH CONCRETE BASE.

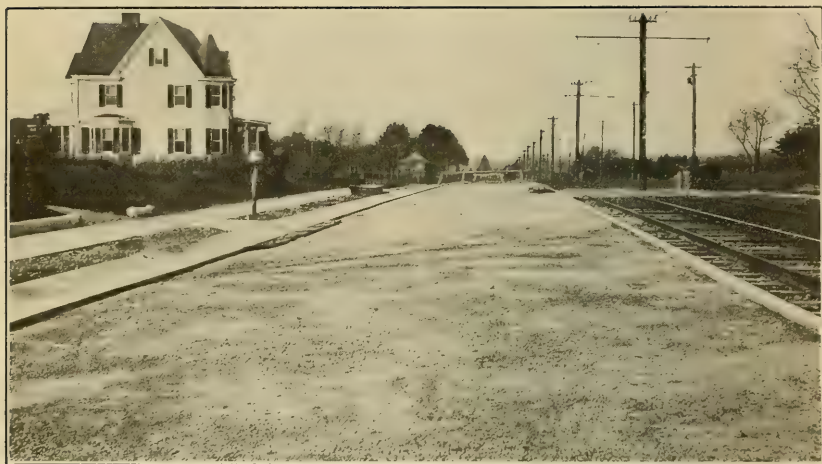
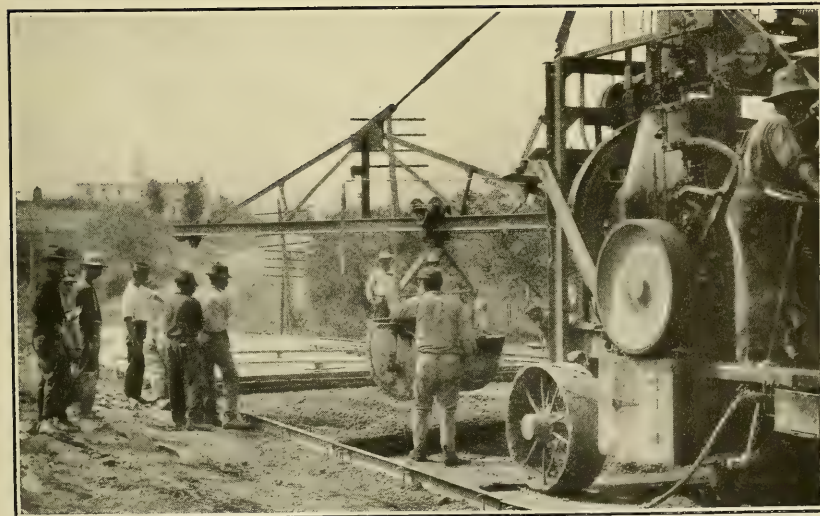
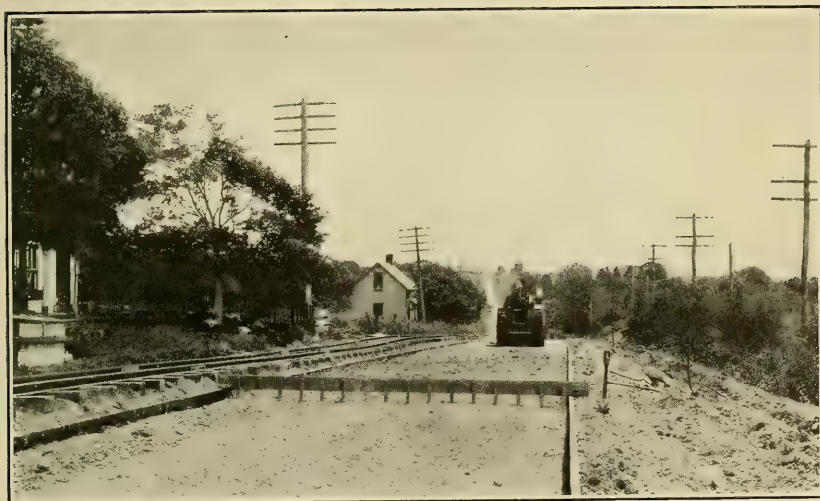


FIG. 1.—CONCRETE FOUNDATION WITH MARGINAL CURBS READY FOR WEARING SURFACE.



FIG. 2.—CONCRETE GUTTER, SHOWING RELATION TO FINISHED HIGHWAY.



CONCRETE FOUNDATION CONSTRUCTION.



CONCRETE ROAD CONSTRUCTION.

rather widely. With the average batch mixer, the minimum time should not be less than about one minute and about 14 or 20 turns of the drum, and if practicable, an automatic timer or counter should be employed to see that this minimum is observed.

2. That the subgrade is damp when the concrete is placed upon it. A special hose should be provided for sprinkling the subgrade and the sprinkling should be done in such manner as not to produce mud. The object of wetting the subgrade is to prevent it from absorbing the water of the concrete, and the amount of sprinkling should be only sufficient to accomplish this purpose.

3. That the concrete is placed with dispatch after it is mixed, and that it is of such consistency that it may be struck off immediately and shaped without danger of the layer becoming wavy or otherwise losing its shape. The concrete should be compacted as it is struck off. This may be done by using the strike board as a tamper, or by some other suitable device.

4. That no concrete is laid during freezing weather and that none of the materials used contain frozen lumps. Freezing of fresh concrete may cause complete failure and nearly always impairs its strength. After concrete has set for four or five days, it is not likely to be damaged by freezing.

5. That the new concrete foundation is protected from too rapid drying out by a covering of earth or other suitable material. The earth covering should be at least 1 inch thick and should be spread as soon as may be without damaging the concrete (ordinarily about 24 hours). The covering should remain on the foundation for about 10 days and should be sprinkled repeatedly and kept moist during this period. No loads whatever should be permitted on the foundation until it is 10 or 12 days old. The earth covering is of especial importance during the hot, dry seasons of summer but is sometimes omitted altogether in the spring or fall seasons when weather conditions are favorable.

6. That no heavy loads are allowed on the foundation until after the road crust has been completed and opened to traffic.

Plates XI and XII illustrate the different steps involved in the construction of a concrete foundation.

SPECIAL CONCRETE FOUNDATIONS.

In addition to the general method described above for constructing concrete foundations, several special methods have been tried, but none of these has proved of sufficient importance to warrant a detailed description. In one or two instances attempts have been made to mix the concrete in place on the road. According to this method, the materials were spread out in proper proportions, water added, and the mass mixed by means of harrowing. According to another method the coarse aggregate is spread and rolled as for a crushed stone foundation, and the voids in the mass then filled, as nearly as practicable, with Portland cement grout mixed very thin and poured over the surface.

A modification of the common method has been employed lately in connection with brick pavement construction. The modification consists essentially in laying the brick before the concrete of the foundation has had time to set, and is really concerned more with the road crust than the foundation. This method promises to be of importance, but since its application is limited at present to only one

type of road, and since it has already been described in the office publications on brick road construction, it will not be discussed further here.

COST OF CONCRETE FOUNDATIONS.

In estimating the cost of a concrete foundation it is necessary to consider the materials and the labor separately. Table 12 shows the quantities of the different materials required to build 100 linear feet of foundation 6 inches thick for the various proportions of mix ordinarily used in foundation construction. In preparing the table the percentages of voids in the coarse aggregate have been assumed as 35 and 45, respectively, for well-graded gravel and average crushed stone. The sand is assumed to be moderately well graded and each barrel of cement is assumed to have a volume of 4 cubic feet.

TABLE 12.—*Showing quantities of materials required for 1 cubic yard of concrete.*

PROPORTION.

Cement.	Sand.	Coarse aggregate.	Coarse aggregate to be well-graded gravel or equivalent.			Coarse aggregate to be average crushed stone or equivalent.			
			Cement.	Sand.	Coarse aggregate.	Cement.	Sand.	Coarse aggregate.	Width (6 inches thick).
			Barrels.	Cu. yds.	Cu. yds.	Barrels.	Cu. yds.	Cu. yds.	Feet.
1	2	4	1.38	0.41	0.82	1.51	0.45	0.90	-----
1	2½	5	1.13	.42	.84	1.24	.46	.92	-----

QUANTITIES.

1	2	4	23.00	6.83	13.67	25.17	7.50	15.00	9
			35.78	10.63	21.26	39.15	11.67	23.34	14
			46.89	12.15	24.30	44.74	13.33	26.67	16
			46.00	13.67	27.33	50.33	15.00	30.00	18
			51.11	15.18	30.37	55.93	16.67	33.33	20
1	2½	5	18.83	7.00	14.00	20.67	7.67	15.33	9
			29.30	10.89	21.78	32.15	11.93	23.86	14
			33.48	12.44	24.89	36.74	13.63	27.26	16
			37.67	14.00	28.00	41.33	15.33	30.67	18
			41.85	15.55	31.11	45.93	17.04	34.08	20
1	3	5	17.83	7.83	13.17	19.33	8.67	14.33	9
			27.75	12.19	20.48	30.08	13.48	22.30	14
			31.70	13.93	23.41	34.37	15.41	25.48	16
			35.67	15.67	26.33	38.67	17.33	28.67	18
			39.63	17.41	29.26	42.96	19.26	31.85	20
1	3	6	16.17	7.17	14.33	17.67	7.83	15.67	9
			25.15	11.15	22.30	27.49	12.19	24.37	14
			28.74	13.74	47.48	31.41	13.93	27.85	16
			32.33	14.33	28.67	35.33	15.67	31.33	18
			35.93	15.93	71.86	39.26	17.41	34.82	20
1	3	7	14.67	6.50	15.17	-----	-----	-----	9
			22.82	10.11	23.60	-----	-----	-----	14
			26.07	11.56	26.96	-----	-----	-----	16
			29.33	13.00	30.33	-----	-----	-----	18
			32.59	14.44	33.70	-----	-----	-----	20

PROPORTIONS.

1	2	5	1.07	0.47	0.79	1.16	0.52	0.86	-----
1	2	6	.97	.43	.86	1.06	.47	.94	-----
1	3	7	.88	.39	.91	-----	-----	-----	-----

In purchasing sand and coarse aggregate for concrete the unit of measure is quite frequently the ton instead of the cubic yard. After the quantities have been estimated from the preceding table, therefore, it may be necessary to convert cubic yards into tons before the cost can be estimated. This can not be done accurately without some definite knowledge as to the relative heaviness of the materials it is purposed to use, but the following list of average weights will afford a means of making an approximate conversion. In using this list it should be remembered that the extreme variations in weights of crushed stone may be as much as 10 per cent in either direction from those shown.

Approximate average weights per cubic yard of various concrete materials.

	Pounds.
Standard Ottawa sand.....	2,500
Average clean bank.....	2,600
Well-graded clean bank sand.....	2,900
Average washed gravel.....	2,700
Well-graded washed gravel.....	3,000
Crushed limestone screened between $\frac{1}{2}$ and 2 inches.....	2,500
Crushed sandstone screened between $\frac{1}{2}$ and 2 inches.....	2,400
Crushed granite screened between $\frac{1}{2}$ and 2 inches.....	2,700
Crushed trap screened between $\frac{1}{2}$ and 2 inches.....	2,800

The cost of quarrying and crushing stone has been discussed in connection with crushed-stone foundations, and need not be discussed further here except to state that stone for use as concrete aggregate must be screened more carefully than when intended merely for use in a crushed-stone foundation. The additional cost occasioned by this extra care should not exceed about 5 or 6 cents per ton where adequate machinery is employed.

In discussing gravel foundations some information as to the cost of screening has been included. In a well-arranged plant the cost of washing and screening should scarcely exceed the average cost for screening alone. Large producers of washed gravel ordinarily market their product at from 30 to 40 cents per ton f. o. b. at the plant. Where the supply of gravel is limited, or the demand is small, the price may be increased greatly; sometimes to more than twice what is given above. The cost of sand at the pit averages about the same as that of gravel.

The cost of mixing and placing concrete may be estimated from the labor required to operate an ordinary street-paving concrete mixer, considered together with the mixer's capacity. There are two sizes of such mixers in common use. The larger size has a batch capacity of about one-half cubic yard and requires about 35 laborers of all classes for its efficient operation, while the batch capacity of the smaller size is about one-third cubic yard and the number of laborers

usually employed in operating it is about 80. The hourly output of the larger size should average about 18 cubic yards of concrete and of the smaller size about 12.5 cubic yards. Assuming the cost of labor at 20 cents per hour and making a reasonable allowance for depreciation of equipment and supervision, the cost of mixing and placing the concrete may usually be estimated at from 60 to 80 cents per cubic yard.

NOTES ON SPECIFICATIONS.

The following notes on specifications are given as typifying what is believed to be the best practice so far developed in connection with the various features of highway improvement that have been discussed in the preceding pages. These notes are given with a view to making the information contained in the text readily applicable to contract work. In order to avoid repetition the notes on materials are separated from those on the methods of construction.

MATERIALS.

Cement.—The cement for use in this work shall meet the requirements of the standard specifications for Portland cement of the American Society for Testing Materials, adopted in 1904 and revised in 1916, serial designation C9-17.

Provisions are made in these specifications for testing and storing the cement. Under certain conditions, if the cement meets the 7-day tests satisfactorily, it need not be held until the results of the 28-day tests are available.

Fine aggregates: Sand. (See Bulletin 555, p. 19.)

Stone or gravel screenings. (See Bulletin 555, p. 10.)

Coarse aggregates: Broken stone or gravel. (See Bulletin 555, p. 9.)

Broken slag. (See Bulletin 555, p. 15.)

Cushion or bedding: Sand. (See Bulletin 555, p. 21.)

Granulated slag. (See Bulletin 555, p. 15.)

Grouting sand. (See Bulletin 555, p. 20.)

Water.—The water used in the mixing of concrete or grout shall be free from oil, acid, alkali, or vegetable matter, and fairly free from clay or silt.

Cobblestones.—Cobble paving shall be constructed of bank or river cobbles, sound in all respects and fairly symmetrical in shape. No stone shall be used which is less than 6 inches or more than 10 inches in its longest dimension or which does not have one lesser dimension at right angles to the length of at least 4 inches. If preferred by the contractor, quarried stones which, in the judgment of the engineer, are equal to the cobbles above specified, may be substituted for the cobbles, provided that the limiting dimensions of the individual blocks of quarried stone shall be the same as those specified for cobbles.

CLAY FARM DRAIN TILE.

NOT EXCEEDING 12-INCH DIAMETER.

[Copied largely from A. S. T. M. Standard Specifications C4-16.]

The tile shall be made from shale, fire clay, or surface clay by such method of manufacture as will insure excellence of product and uniformity in quality.

The presence in the tile of visible grains or masses of caustic lime, iron

pyrites, or any other minerals which are known to cause slaking or disintegration of the tile shall be valid ground for rejection, unless satisfactory proof be submitted that the tiles are permanent and durable, and that the objectionable minerals are not present in quantity or condition to work damage.

The physical tests of the tile shall include strength and absorption tests made in accordance with the standard specifications for drain tile adopted by the American Society for Testing Materials in 1916. The average ordinary supporting strength shall be not less than 800 pounds per linear foot. The average absorption by the boiling test shall not exceed 11 per cent for shale and fire-clay tile, or 14 per cent for surface-clay tile. Tile made of mixed clays shall conform to the absorption requirements for surface-clay tile when the proportion of surface clay is 75 per cent or more, and to the requirements for shale and fire-clay tile for other proportions.

All tile shall be inspected visually (1) to cull and reject imperfect individual tiles, and (2) to determine whether the tiles, independently of meeting the chemical and physical requirements, comply with the specifications of general properties, especially as stated hereinafter.

The bore of all tile shall be approximately circular, the tile shall be approximately straight, and the ends of the tile shall be so regular and smooth as to readily admit of making joints by turning and pressing together adjoining tile.

The sizes of drain tile shall be designated by their interior diameter.

The tile shall have a minimum length of 12 inches.

The tile shall be substantially uniform in structure throughout, as determined by an examination of fractured surfaces.

The tile shall have a clear ring when stood on end and while dry tapped with a light hammer.

The tile shall be reasonably smooth on the inside.

The tile shall be free from cracks and checks extending into the body of the tile in such manner as to decrease the strength appreciably. Tile shall not be chipped or broken in such manner as to decrease the strength materially or to admit earth to the drain.

The tile shall not vary from straight by more than 5 per cent of its length. The maximum and minimum diameters of the same tile, or the average diameter of adjoining tile shall not differ by more than 85 per cent of the thickness of the tile wall. The average diameter of a tile must not be less than 95 per cent of the specified diameter. Exterior blisters, lumps, and flakes which do not weaken the tile and are few in number will be allowed, but only when their thickness does not exceed 25 per cent of the thickness of the tile wall and when their diameters do not exceed 20 per cent of the internal diameter of the tile.

The vendor may appeal from decisions of the inspector on questions of strength or structure when such decisions are based on visual inspection alone, in which case the point at issue shall be determined by standard physical tests, the cost of which shall be paid by the appellant if the inspector was right, or by the purchaser if his inspector was in error.

CEMENT OR CONCRETE TILE.

Wherever cement or concrete tile is called for the tile used shall be equivalent in all respects to the quality and strength of clay drain tile, and shall conform to Specification C4-14 of the American Society for Testing Materials.

CONSTRUCTION.

SIDE DITCHES.

The side ditches, when completed, shall have the general cross section indicated on the plans, and shall conform in all respects to the lines and grades furnished by the engineer. Where the exact cross-sectional dimensions are not indicated on the plans for each particular section of the road, these dimensions will be fixed by the engineer, with a view to providing adequate drainage without erosion, and shall be strictly observed by the contractor.

In making excavations for side ditches care shall be exercised to see that the earth is not disturbed below the proposed bed of the ditch, and wherever it is necessary to fill in at the sides of a ditch, the material shall be thoroughly tamped as it is deposited so that it will offer practically the same resistance to erosion as the rest of the ditch bed. The ditch, when completed, shall present a smooth uniform bed and shall be kept free from obstructions during all subsequent stages of the work.

The material excavated from side ditches will be paid for at the price bid for ditch or gutter excavation.

COBBLE GUTTERS.

Cobble gutters shall be constructed as shown on the plans or as directed by the engineer in writing, and, when completed, shall conform in all respects to the required cross section, line, and grade. The method of construction shall be as follows:

TRENCH.

Along the line of the gutter, as staked out by the engineer, a trench shall be excavated to the full width of the gutter and to a depth of 12 inches below the gutter grade. When complete, the trench shall be true to line and grade and the bottom shall be compacted and firm, and wherever filling is necessary in order to bring any part of the trench to the required cross section, the material filled in shall be thoroughly tamped.

FOUNDATION.

Upon the bottom of the trench, prepared as described above, shall be spread a layer of crusher-run stone or gravel, such that when thoroughly tamped and compacted it will have a depth of 6 inches.

After the foundation material is spread to the necessary depth it shall be thoroughly compacted, by tamping, or otherwise, until the upper particles are not disturbed by men walking on the surface of the foundation. The foundation, when complete, shall be approximately parallel to the surface of the finished gutter.

SAND BEDDING.

After the foundation has been prepared as above described it shall be covered with a layer of bedding sand. This layer shall have a loose depth of about 2 or 3 inches as may be required to bring the gutter stones which are bedded in it to the required cross section.

SETTING COBBLES.

In setting the cobbles those which are largest and most nearly perfect shall be picked out and set in the edges and middle row of the gutter. All of the

cobbles shall be firmly bedded in the bedding sand and shall fit snugly, one against the other. They shall be set with their longest dimensions lengthwise of the gutter and shall be so arranged as to break joints roughly. As the setting proceeds each cobble shall be rammed with a hand rammer weighing not less than about 20 to 30 pounds until it no longer yields under the rammer, and any irregularities that may be caused by ramming shall be corrected by taking up and resetting the affected portion. When the cobbles have been set and rammed as above described the gutter shall have the required cross section and shall present a uniform appearance. Where the gutter is to be grout filled care shall be exercised in setting and ramming the cobbles to see that the bedding sand is not forced up into the joints above the center of the cobbles.

SAND FILLER.

Where the plans provide for the joints of the cobble gutter to be filled with sand the sand used for this purpose shall conform to the specification for bedding sand and the filling of the joints shall proceed along with the setting and ramming of the cobbles. The sand shall be spread and swept over the surface of the gutter in sufficient quantity to leave a decided surplus on the surface after the joints have been completely filled. While the sand is being spread the entire surface of the gutter shall be repeatedly rammed so as to jar the sand thoroughly into the joints. After the joints are filled the gutter shall be true to the grade and cross section shown on the plans, and all of the cobbles contained in the paving shall be well bedded and so firmly held in place.

GROUT FILLER.

Where the plans provide for the joints of the cobble gutter to be filled with Portland-cement grout the grout used for this purpose shall be prepared by mixing together, by volume, 1 part of Portland cement, 2 parts of sand, and sufficient water to produce a consistency about equal to that of ordinary cream. The sand and cement shall first be thoroughly mixed dry, and the water shall then be admixed. After the grout is mixed it shall be kept constantly agitated until it has all been taken from the containing vessel and used in the joints. At the time the grout is applied the joints shall be entirely free from sand or other foreign material which extends above the center of the cobbles. The grout shall be repeatedly applied and swept back and forth over the surface of the gutter with a suitable broom or squeegee until the joints are filled flush and the surface of the gutter presents a smooth uniform appearance.

After the grouting is completed as above described the gutter shall be protected for at least two weeks until the grout hardens. In case drying weather prevails during this period the gutter shall be kept covered with earth or some other suitable material and shall be kept moist by occasional sprinkling with water.

CONCRETE GUTTERS.

Concrete gutters shall conform to the cross-section drawing shown on the plans for such gutters and shall be true in all respects to the line and grade as staked out by the engineer.

TRENCH.

Along the line of the gutter as staked out by the engineer a trench shall be excavated to the full width of the gutter, with allowance for necessary forms, and to such depth, grade, and cross section that when the gutter is constructed,

as hereinafter specified, all parts of it will serve the required dimensions and conform in all respects to the plans and engineer's stakes. Wherever filling is necessary in order to bring any part of the trench to the required cross section, the material filled in shall be thoroughly tamped, and when the trench is complete it shall have a compacted and firm bed throughout.

FOUNDATION.

(If the climatic and subgrade conditions are such as to make a crushed-stone or gravel foundation necessary, the specification already given for the foundations of cobble gutters may be inserted here.)

FORMS.

After the trench and foundation have been prepared as above specified, suitable forms of either wood or steel shall be provided to receive the concrete paving. The top edges of the forms shall conform accurately to the line and grade required for the gutter. On curves in the alignment of the gutter the form sections shall be sufficiently short to give the appearance of a continuous arc rather than a succession of chords. The forms shall be sufficiently well braced to overcome all tendency to bulge out when the concrete is placed against them and shall have a bearing sufficiently uniform and stable to prevent all sagging while the concrete is being struck off and tamped. The bracing shall be so arranged as not to interfere in any way with the striking off and finishing of the gutter. The forms shall be clean when used and shall be smooth surfaced for all exposed faces.

CONCRETE.

The concrete shall be mixed in the volumetric proportion of 1 part cement, 2 parts of sand, and 4 parts of coarse aggregate, with sufficient water to produce a mixture of such consistency that the concrete will hold its shape after being placed in the gutter, and finished to the required cross section. The mixing shall be thoroughly and uniformly done, either by hand or in a mechanical mixer previously approved by the engineer. Hand mixing shall be done upon a watertight platform of such area as to afford ample room for turning and mixing the largest batch which it is purposed to mix at any one time without danger of mortar escaping over the edges of the platform. The procedure in mixing concrete by hand shall be as follows for each and every batch:

1. Mix the cement and sand dry until the mixture is of a uniform color throughout.

2. Spread the coarse aggregate over the mixed sand and cement, add water, and turn the whole mass three or more times until every particle of the aggregate is thoroughly coated with mortar.

The turning should be systematically done, beginning at one end and turning outward from the pile. In this way the entire mass is turned over and no core or center left undisturbed. The second turning should be at right angles to the first, and the third again at right angles to the second.

The concrete shall be placed in the forms immediately after the mixing is finished, and shall be spread, struck off, tamped, and finished before sufficient time has elapsed for initial set to begin. The foundation shall be moist when the concrete is placed. The striking off and tamping shall be done with templates shaped to conform with the cross section of the gutter and so operated as to insure a uniform surface. The finishing shall be done with a wooden float and when completed the surface shall present a uniform mortar surface entirely

free from honeycombed spots, and no point in the surface shall deviate from the elevation indicated on the plan by more than one-quarter inch.

JOINTS.

Joints shall be made in the gutter at intervals of approximately 20 feet. The joints shall be one-quarter inch in thickness and shall be made by means of bituminous felt boards, which shall be perpendicular to the center line of the gutter and shall extend entirely through the concrete throughout the width of the gutter.

PROTECTION.

After the gutter is completed as above described the concrete shall be protected from too rapid drying by means of a suitable covering. In drying weather the gutter shall be covered with canvas as soon as it is finished. The canvas shall be spread in such a manner as not to mar the surface of the gutter and shall be left in place for about 24 hours, until the concrete has hardened sufficiently not to be damaged by the spreading of an earth covering. It shall then be removed and the entire surface of the gutter covered with a layer of earth or sand about 2 inches thick. The earth covering shall remain on the concrete and be kept thoroughly moist for a period of two weeks, and during this period the concrete shall not be subjected to loads of any kind.

TILE DRAINS.

Tile drains shall be constructed where indicated on the plans and when completed shall conform accurately to the lines and grades established by the engineer. The work of constructing tile drains shall, in all cases, begin at the outlet end of the drain and proceed uphill.

TRENCH.

Trenches for tile drains shall be excavated to a uniform grade such that when the tile is laid it will rest on the bottom of the trench and have the required elevation at all points, and this shall be assured by means of a taut wire or cord stretched between standards established from the engineer's stakes. The width of the trench shall be such that the tile may be readily laid according to the required alignment without the necessity of gouging into the banks of the trench. The bottom width shall in no case be less than 10 inches. Where stone occurs in the trench it shall be excavated to a depth of at least 6 inches below the bottom of the tile, and the space thus made shall be refilled with earth of suitable character and thoroughly tamped before the tile is laid. Where the bottom of the trench is not sufficiently stable, in the judgment of the engineer, to support the tile without danger of unequal settlement 1 by 6 inch wooden boards shall be placed flat in the trench for the tile to rest upon. Where boards are required, the contractor will be paid for the actual cost of the boards delivered on the work and for the work of placing them, plus 10 per cent.

LAYING THE TILE.

In laying the tile the successive sections shall each be turned until the abutting ends fit closely together, and such small openings as may be unavoidable at the joints shall be made to come at the bottom. Any opening more than one-quarter inch wide shall be covered with either broken tile or cement mortar. Wherever two drains come together the junction shall be made by means of T or Y branches and not by cutting two straight sections of tile to fit at an angle.

Where curves occur in the alignment the tile shall be laid accurately to the arc of the curve, and if straight sections are used the joints shall be covered with broken tile or cement mortar.

As soon as the tile is laid as above provided and approved by the engineer, it shall be covered to a depth of about 6 inches with earth which contains no stones larger than 1 inch in diameter and which shall be thoroughly tamped as it is placed. The earth used for this purpose shall be moist when it is placed over the tile and shall be of such quality that it will not run into the tile through the joints. The covering shall be very carefully done so as not to disturb the tile in any way.

After the tile has been carefully covered as above provided, the entire trench shall be back filled. The material used for back filling shall be thoroughly tamped as it is deposited in the trench, and if the engineer so requires, the material of the back fill shall be heaped above the proposed surface over the trench so as to allow for subsequent settlement.

OUTLET.

Tile drain outlets shall be protected with head walls as shown on the plans, and shall be covered with suitable gratings of iron or steel. The upstream end of the drain shall be filled with stone, concrete, or some other durable material which will prevent earth from entering the drain at this point.

ALTERNATE SPECIFICATION FOR BACK FILLING THE TRENCH AROUND AND OVER A DRAIN THROUGH STIFF CLAY.

Before the tile is laid the bottom of the trench shall be covered with a 2-inch layer of gravel or crushed stone of such size that all would pass through a 1½-inch mesh screen and be retained on a one-half inch mesh screen.

(Insert specification for laying tile.)

After the tile is laid as above specified it shall be covered to a depth of 1 foot with gravel or crushed stone of the kind specified for the bottom layer. This covering shall be thoroughly tamped over and around the tile, but in such a manner as not to disturb the tile in any way. The trench shall then be filled to the required depth with gravel or crushed stone of the size elsewhere defined in these specifications for "No. 1 stone," and the entire back fill shall be thoroughly tamped as it is deposited in the trench. The work of making the back fill shall be so carried on as to prevent sand, silt, earth, or other foreign material from getting into either the drain or the interstices of the back fill, and in case this requirement is not observed the contractor may be required to rebuild the drain entirely at his own expense.

GRADING.

Grading shall include the moving of all earth, stone, and any other material that may be encountered, all filling, borrowing, trimming, picking down, shaping, sloping, and all other work that may be necessary to bring the road and subgrade to the required grade, alignment, and cross section, the clearing out of waterways and old culverts, the excavation of all necessary drainage and outlet ditches, the grading of a proper connection with all intersecting highways, the grubbing up and clearing away of all trees, stumps, and boulders within the lines of the improvement, and the removal of any muck, soft clay, or spongy material which will not compact under the roller, so as to make a firm, unyielding subgrade.

All trees, stumps, and roots within the limit of the improvement shall be grubbed up so that no part of them shall be within 6 inches of the surface of the ground or within 18 inches of the surface of the subgrade.

Embankments shall be formed of good, sound earth and carried up full width. The earth shall be deposited in layers not more than 1 foot in thickness, and each layer shall be rolled or otherwise suitably compacted by distributing traffic uniformly over the surface until thoroughly compacted.

All existing slopes and surfaces of embankments shall be plowed or scarified where additional fill is to be made, in order that the old and new material may bond together. When sufficient material is not available within the fence lines to complete the embankments, suitable borrow pits, from which the contractor must obtain the necessary material, will be designated by the engineer. If there is more material taken from the cuts than is required to construct the embankments as shown on the plans, the excess material shall be used in uniformly widening the embankments or shall be deposited where the engineer may direct. Wherever embankments are formed of stone the material shall be carefully placed, so that all large stones shall be well distributed and the interstices shall be completely filled with smaller stone, earth, sand, or gravel, so as to form a solid embankment.

During the work of grading, the sides of the road shall be kept lower than the center and the surface maintained in condition for adequate drainage.

The grading of any portion of the road shall be complete before any surfacing material is placed on that portion; and where the plans do not call for any substantial change in the grade of any existing section of the road the surface shall be completely scarified to a depth of 3 inches or more before the subgrade is prepared.

SUBGRADE.

The subgrade, or that portion of the road upon which the roadway is to be constructed shall consist of good, sound earth brought to the proper elevation, alinement, and cross section, and shall be rolled until firm and hard. The rolling shall be done with a power roller, weighing not less than 10 tons and not more than 15 tons. Should earth be encountered which will not compact by rolling, so as to be firm and hard, it shall be removed and suitable material put in its place, and that portion of the subgrade shall be again rolled. When the rolling is completed the surface of the subgrade shall conform to the cross section shown on the plans, and shall have the proper elevation and alinement, and shall be so maintained until it is covered by the foundation or road crust.

CRUSHED-STONE FOUNDATION.

Where a crushed-stone foundation is called for on the plans it shall be constructed after the curbs are set and in two courses of such thickness that the finished foundation will have the required depth shown on the plans.

The first course of stone shall consist of a single layer of No. 1 stone spread uniformly to a depth of not more than 6 inches before compacting. The stone shall be spread by hand from dumping boards or from dump wagons of a type that will distribute each load of stone evenly over that part of the subgrade to be covered by the load.

After the crushed stone of the first course has been spread to the required depth, it shall be rolled until it is thoroughly compacted and firm with a three-wheeled power roller weighing not less than 10 tons and not more than 15 tons. The rolling shall begin at the curbs and progress gradually toward the crown. All irregularities and depressions that may develop shall be immediately cor-

rected with No. 1 stone, and the rolling shall continue until the stone is well compacted and the surface is uniform in grade and cross section.

The second course of stone shall consist of a single layer of No. 2 stone spread uniformly to a depth not exceeding 4 inches. The stone shall be spread and rolled in the manner prescribed for the first course. When completed the surface of the second course of crushed stone shall be smooth, firm, well compacted, and continuous, and shall have the cross section and grade indicated by the drawings.

After the second course of stone has been spread, rolled, and completed as above specified, screenings shall be spread uniformly over the surface to a depth of approximately one-half inch. The spreading shall be done with shovels from piles along the road, from dumping boards, or from carts. In no case shall an entire load of screenings be dumped directly upon the second course.

After the screenings are spread they shall be dry rolled until the voids of the second course are filled. The foundation shall then be sprinkled with water from properly constructed sprinkling wagons and rolled with a power roller of the type and weight specified for the first course. The amount of water used shall be sufficient to wet the stone thoroughly, but shall be put on in such quantity and manner as not to wet and soften the subgrade. Screenings shall be added and the sprinkling and rolling continued until the surface ceases to show the marks of the roller and a grout of water and rock dust flushes ahead of the roller.

After the foundation is completed, as above specified, no materials or traffic shall be placed or allowed upon it for at least 24 hours.

TELFORD FOUNDATION.

The Telford foundation shall conform to the cross-section drawings shown on the plans and when completed shall be true in all respects to the line and grade as staked out by the engineer.

TELFORD STONES.

The stone used shall be sound and durable and, in the judgment of the engineer, equal in quality to that obtained from the ——— quarry located at ———. The individual blocks shall be approximately rectangular in shape and shall conform to the following limiting dimensions:

Depth—Equal to the depth of the foundation as shown on the plans.

Length—Not less than the depth and not greater than one and one-half times the depth.

Width—Not less than one-half the depth and not more than the full depth.

SETTING THE TELFORD.

The stones shall be set by hand with their long dimensions at right angles to the direction of the road and in approximately straight courses. They shall break joints roughly in the courses and shall fit in snug contact, one against the other. Each stone shall rest on its broadest edge and shall be rammed to a firm uniform bearing on the subgrade.

After the stones are set as above provided all interstices that appear in the surface of the foundation shall be filled with spalls which shall be firmly wedged into place by means of a hand hammer. All projecting stones which extend more than 1 inch above the established surface of the foundation shall

be broken off as the wedging proceeds. When this process is completed the foundation shall present a true and uniform appearance and shall contain no stones that may be loosened or shaken with the hand or foot.

ROLLING.

After the foundation has been wedged and surfaced as above provided it shall be thoroughly rolled with a roller weighing not less than 10 tons. Any depression that may develop under the roller shall be corrected by taking up and resetting the affected portion, and the portion thus reset shall be again rolled. When the rolling is finished the foundation shall be uniformly of the required grade and cross section and every stone which it contains shall be firmly wedged in place, and the surface shall be free from all loose stone or other material which would be objectionable in the road crust.

CONCRETE FOUNDATION.

Upon the subgrade prepared as herein specified shall be laid a concrete foundation of the width and thickness shown on the plans. The subgrade shall be wet but not muddy when the concrete is placed upon it. The concrete shall be composed of the following materials, by volume: One part cement, 3 parts sand, and 5 parts of gravel, crushed stone, or crushed slag, and sufficient water to form a quaky mass, and shall be thoroughly mixed in a machine mixer of the batch type, so constructed and operated that the thorough mixing of the materials will be assured. The concrete shall be so delivered to its place on the subgrade as not to cause or permit any separation of the materials. Wheelbarrows or other devices used for measuring the materials shall be of uniform capacity. The concrete shall be deposited in place immediately after it is mixed and shall be well compacted as fast as it is placed. The top surface shall be smoothed by troweling with shovels or by some other means approved by the engineer, and when completed shall not vary more than one-half inch from the proper shape and grade, as shown on the plans and profiles. The concrete foundation shall be kept wet by sprinkling with water during the first four days after it is laid. No hauling over it or rolling or tamping of brick upon it will be permitted for seven days after it is placed, and during this time it shall be properly protected from injury. Concrete shall not be mixed when the temperature of any of the materials is less than 35° Fahrenheit. Concrete shall not be used after it has begun to show evidence of setting, and no concrete which has once set shall be used as material for mixing a new batch.

FLANGE CURBS.

Concrete curbs shall be built on the foundation as shown on the plans. The concrete shall be composed of the following materials, by volume: One part of cement, 1½ parts of sand, 3 parts of gravel or crushed stone, and water. The materials shall be thoroughly mixed in a machine mixer of the batch type or by hand. If the mixing is done by hand, it shall be done upon a water-tight platform with raised edges, in the following manner: The sand and cement shall be thoroughly mixed dry and spread out upon the mixing platform, and upon this dry mixture shall be spread the coarse aggregate. Water shall then be poured over the aggregate in such an amount that the resultant concrete will be of a quaky consistency. The whole mass shall then be turned with shovels until all of the materials are thoroughly mixed. The concrete for the curb shall be placed upon the foundation before the concrete of either the curb or the foundation has taken its initial set, and care shall be taken, such as rough-

ening the concrete of the foundation and tamping the concrete of the curb, to insure that the curb will be firmly bonded to the base. The concrete shall be well tamped and spaded along the forms, so that when they are removed there will be no open and porous places on the sides of the curb. The top surface of the curb shall be floated or troweled to a smooth finish. The forms for the curb shall be smooth, clean, free from warp, and of sufficient strength to resist springing out of shape. They shall be well staked and braced, and the top edges shall be at the same height and set true to line. To protect the curb from drying out too rapidly it shall, within 12 hours after it is placed be covered with gunny cloth, which shall be kept wet for five days.

SEPARATE CONCRETE CURBS.

Where the plans call for concrete curbs separate from the foundation they shall be constructed before the subgrade is finally completed and shall have the cross section shown on the plans. Such curbs shall be constructed in sections not less than 6 feet and not more than 12 feet in length and shall be true to grade and alignment.

The specification already given for concrete curbs constructed in combination with the foundation shall also apply to curbs constructed separate from the foundation as regards proportioning, mixing, and placing the concrete, constructing the forms, and all other features of construction which are not covered on the plans or in this specification.

STONE CURBS.

Where stone curbs are required, they shall be hauled and set before the subgrade is finally completed. The curbs shall be set to line and grade and shall be securely bedded in broken stone, gravel, or firm earth. In preparing the trenches for the curbs great care shall be exercised to see the material upon which the curb is to be set is well compacted, firm, and hard.

Stone curbing shall be quarried from hard, tough, homogeneous stone. The individual blocks shall have the cross section shown on the plans and shall be not less than 4 feet in length. Each block shall be free from seams and all other imperfections and shall be neatly dressed and finished on all exposed faces.

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BULLETIN No. 725

Contribution from the Bureau of Markets
CHARLES J. BRAND, Chief



Washington, D. C.

October 22, 1918

A PRELIMINARY STUDY OF THE BLEACHING OF OATS WITH SULPHUR DIOXID.¹

By GEORGE H. BASTON, *Assistant Grain Supervisor.*

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INTRODUCTION.

BLEACHING OATS with sulphur dioxid is a practice that has caused a great deal of controversy and discussion during the past few years. During the past score of years the commercial bleaching of oats and barley has greatly increased until, at the present time, this process is carried on to a considerable extent in nearly all our larger oat-producing sections, the fundamental object being to improve the appearance of the product which is to be placed upon the market, and it was with a view to ascertaining the merits of this practice that these investigations were undertaken.

The character of the seasons in which oats are grown, and particularly the weather conditions prevailing at harvest time, have an influence upon their quality, condition, and appearance and deter-

¹ Other publications pertaining to this subject are:

Circular 40, Bureau of Plant Industry, U. S. Department of Agriculture: "A Simple Method of Detecting Sulphured Barley and Oats," by W. P. Carroll.

Circular 74, Bureau of Plant Industry, U. S. Department of Agriculture: "The Sulphur Bleaching of Commercial Oats and Barley," by LeRoy M. Smith.

Reprint from Circular 111, Bureau of Plant Industry, U. S. Department of Agriculture; "Improved Apparatus for Detecting Sulphured Grain," by George H. Baston.

Food Inspection Decision 145, Bureau of Chemistry, U. S. Department of Agriculture: "Bleached Oats and Barley".

Service and Regulatory Announcements 15, Bureau of Chemistry, U. S. Department of Agriculture: "Oats Bleached with Sulphur."

Service and Regulatory Announcements 16, Bureau of Chemistry, U. S. Department of Agriculture: "Oats Bleached with SO₂ and Oats Containing Added Barley."

mine quite largely the manner in which they are subsequently handled. Oats grown and harvested in a dry season are usually sufficiently bright and bleaching is not necessary to give them a good salable appearance. It is only upon oats which are harvested in a wet season that sulphur bleaching is practiced to any considerable extent, although a certain percentage of the lower grades of oats of all crops have been bleached during the past several years.

These investigations were begun in 1915, and it is deemed advisable to present at this time the data in reference to the methods most commonly used, the results obtained by these methods, and the effects of bleaching on the grain itself. Many phases of the problem have not been investigated as yet, or sufficient data has not been obtained to justify their publication at this time. The attitude of the Department of Agriculture regarding the sulphur bleaching of oats is given in Service and Regulatory Announcements Nos. 15 and 16 of the Bureau of Chemistry.

METHOD OF BLEACHING OATS COMMERCIALY.

The method of bleaching oats and barley commercially is practically the same throughout the country, with the occasional exception of a few changes in the technique that have been made by the individual operator, either better to adapt the process to his peculiar needs, or to give him what he considers a product of better quality. Two methods generally are in use, and these methods are practiced interchangeably by individual operators. These two processes are known as the cold process and the warm process, the only difference being that in one case steam is used to moisten the grain, and in the other cold water is used. The apparatus consists of a tower which is constructed of wood or concrete, an oven for burning the sulphur, a cooling chamber, a suction fan for drawing the fumes from the cooling chamber to the tower, where they are brought in contact with the oats, and a jet for injecting steam or water as the oats enter the tower. Fumes resulting from burning sulphur are drawn up through the moist grain while at the same time the grain runs from the top of the tower to the bottom, bringing as nearly as possible every kernel in contact with the sulphur fumes. Fumes of burning sulphur are sulphur dioxide (SO_2), which when combined with water form sulphurous acid (H_2SO_3), SO_2 plus $\text{H}_2\text{O} = \text{H}_2\text{SO}_3$, an active bleaching agent. It can readily be seen that the addition of water in some form is necessary for the formation of sulphurous acid and an ultimate bleaching of the product. After the oats have passed through the bleaching tower, they are usually run into a bin and allowed to stand over night, when they are cooled or dried as necessity may require. In the event that any considerable amount of water has been added during the process, it is usually necessary to dry out this excess moisture before the

grain can be shipped with safety. Some operators prefer to add as little moisture as possible, in which case the product merely requires cooling before shipment. Others maintain that they get a better-appearing product by adding considerable moisture, and then drying out the excess before shipment.

The bleaching of oats and barley as practiced at the present time is a continuous process after the apparatus has once been set in motion, and very little attention is required except to see that the proper supply of sulphur is kept in the furnace, the proper amount of water is added, and that the grain is kept at a uniform flow. Some of the largest and most efficient bleaching plants have capacities of 2,000 bushels of grain per hour. Photographs of sulphur-bleaching apparatus are shown in figures 1, 2, and 3, which illustrate some of the leading types of commercial bleachers.

CHARACTER OF INVESTIGATIONS.

In the fall of 1915, samples of oats were collected from representative sections in which the commercial bleaching of oats is practiced to a considerable extent, and these samples were carefully examined and analyzed. The analyses of samples from the same lots of grain before and after bleaching were compared. Using these data as a basis for further investigations, additional experiments were undertaken. Visits were made to some of the most important elevators throughout the Middle West that operate bleachers. Samples of as many different grades and qualities of oats as possible were obtained and studied. These were bleached by the regular process in vogue at the elevator, and also by modifications of this method which suggested themselves to the writer or were suggested by the operator of the elevator. Careful attention was paid to the amount of water absorbed, the atmospheric conditions, and the condition and appearance of the oats before and after bleaching. An endeavor was made at all times to improve if possible the appearance of the final product.

Each different grade or quality was carefully studied before and after treatment, and as many types of damaged oats as possible were obtained and examined. The effect of bleaching on each kind

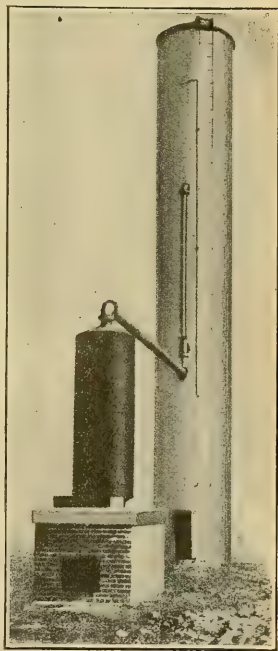


FIG. 1.—A modern grain bleacher.

of damaged grain, such as weather stained, heat damaged, bin burned, and ground damaged, was carefully noted. This same line of experimentation was carried on at several representative points in order to

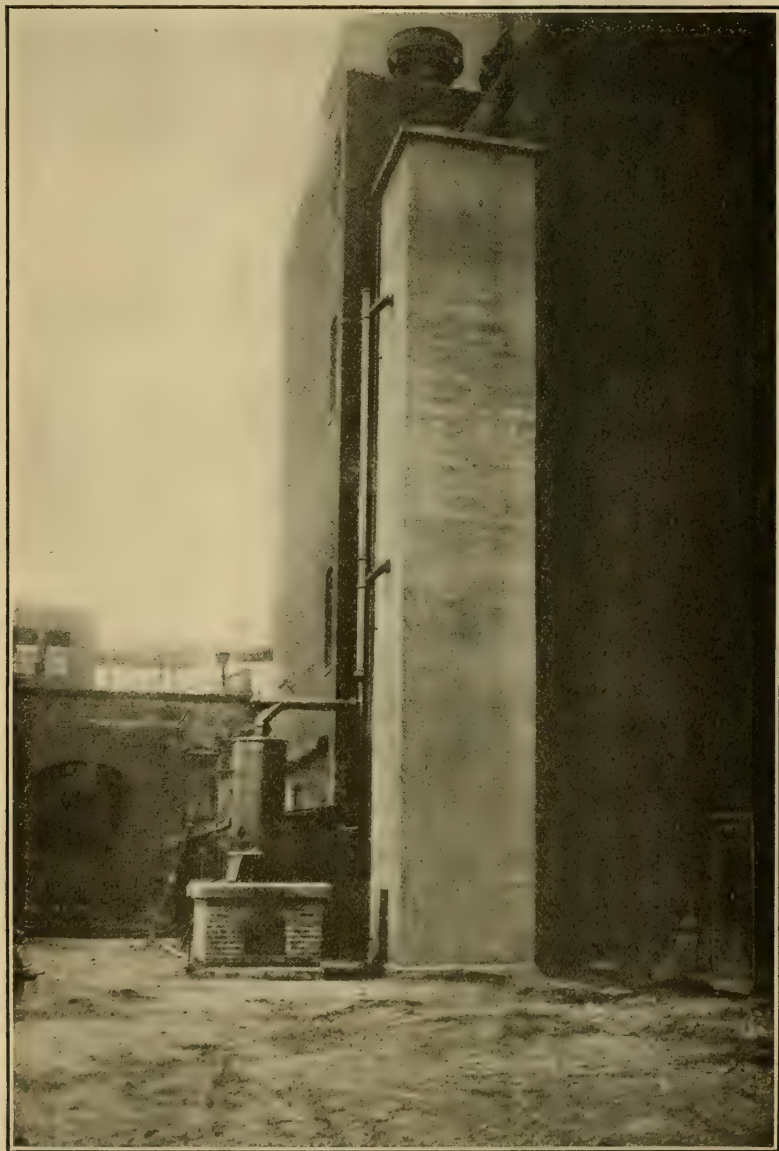


FIG. 2.—A grain bleaching apparatus with square tower. This type is in very common use throughout the Middle West.

get the benefit of varying conditions. Acknowledgment of appreciation is made for the assistance and cooperation given by the owners and operators of the elevators where experiments were conducted.

In studying the comparisons between the natural and the sulphur-bleached grain, careful consideration was given to many sides of the problem. The comparisons, however, in this publication are those

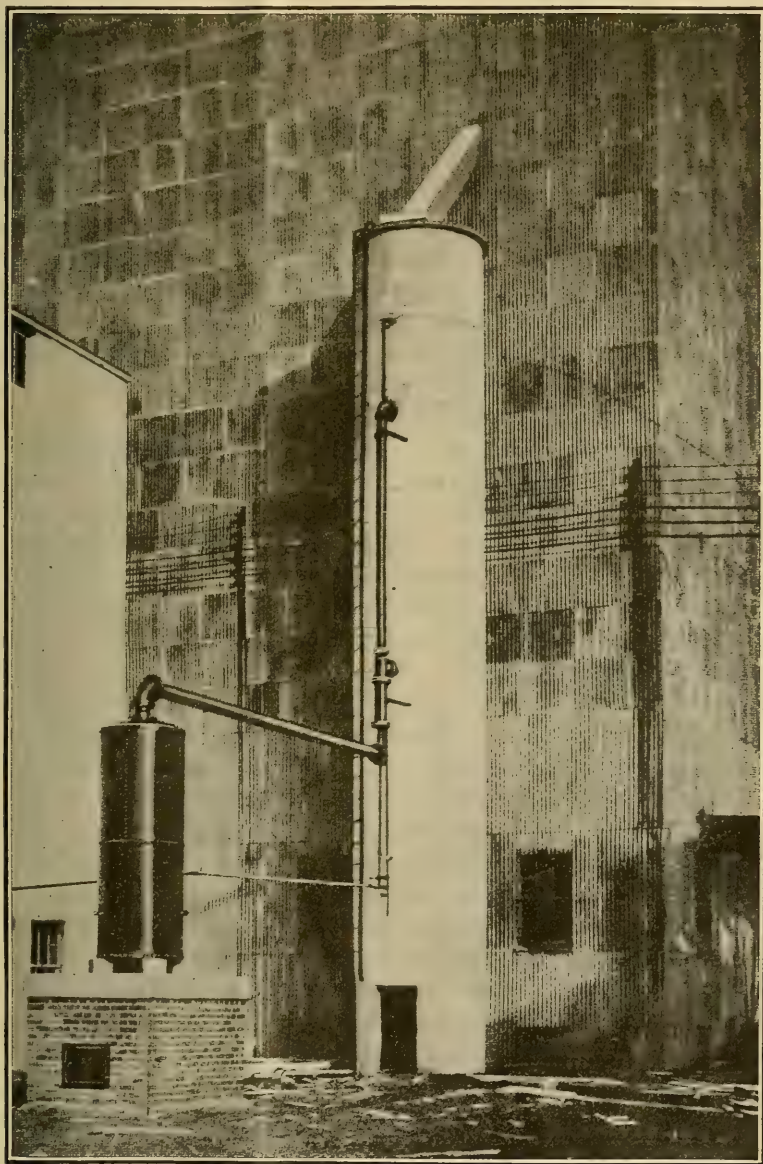


FIG. 3.—A modern bleaching plant with round tower, showing the intake for oats which leads from the elevator to the bleaching tower.

of laboratory tests—chemical, mechanical, and physical. The comparison of the value of the grain as a food product before and after bleaching is a separate problem, the study of which has but recently been undertaken by the Department of Agriculture.

On examination of the table shown, in detail, in the appendix, it is found that almost the same conclusions hold true for the entire table. The percentage of germination, which is a very important factor from the standpoint of the planter, is in almost every case reduced by bleaching, and in some instances the power of germination is killed entirely. It will be noted that the percentage of kernels appearing damaged to the eye is less after bleaching. There is a larger difference, however, in the percentage of kernels damaged by agencies other than heat, although the heat-damaged kernels are considerably less in number in the bleached grain. As will be noticed in pages 10 and 11 of the table, badly bin-burned oats were bleached, and in these two particular lots the oats appearing sound to the eye were increased in lots Nos. 89242 and 89245 from 14.4 per cent before bleaching to 26.6 per cent after bleaching, and in lots Nos. 88672 and 88679 from 28 to 56 per cent, showing that the appearance of even badly bin-burned grain can be substantially raised by the bleaching process.

By examining the table closely, several very interesting facts will be observed. The germination of oats is shown to be materially reduced by sulphur bleaching. The largest reduction is in sample No. 88087, which germinated 97.5 per cent before treating and 9.5 per cent after treating, or a total reduction in germination of 88 per cent caused by sulphuring. In nearly every set of samples in this table, however, a large reduction will be noticed in the percentage germination of samples that have been sulphured. The fact that in almost every instance the bleaching of oats reduced the germination to some extent, and in some instances killed the power of germination entirely, is a serious factor whenever the grain is to be considered for seed. Thanks are due to the seed-testing laboratory of the Bureau of Plant Industry for making the germination tests.

Too much attention can not be paid to the quality of seed, for the same amount of time, labor, and money is required to sow a field of oats, whether the viability of the seed oats be high or low, and the product will be influenced directly by the percentage germination of the seed. A casual observer is probably more likely to be misled as to the true quality of oats than of any other grain for seeding purposes, because oats that have been sulphured present a very bright, clean appearance; therefore special care must be taken to ascertain whether this appearance is due to bleaching by sulphur or whether it is natural. It is not an uncommon practice throughout the smaller oat-growing areas for farmers to use for seed, oats that have been purchased for feeding purposes, especially when these oats appear to be of good quality. Usually very poor yields are secured when this is done because these oats may have been sulphur bleached and the con-

sumer not be aware of the fact. Seed men generally buy their oats under contracts stipulating that such oats shall germinate not less than a specific percentage, and further that they shall not be sulphur bleached. This provision, of course, safeguards the farmer when he buys oats from a seedsman who states that such oats are suitable for seed. However, as at present there is no general regulation governing oat handling in intrastate transactions which requires that sulphured oats are to be labeled as such, the farmer generally is without protection and often sows oats that have been sulphured because he has no knowledge of such condition. Some growers are not acquainted with the sulphur-bleaching process, and do not know that this process injures the germination.

In the column headed "Sulphur reaction" are shown the results of a qualitative determination, indicating whether the oats in question had been sulphured or not.¹ In the column above referred to four designations are shown, namely: None, Slight, Medium, and Heavy, which indicate whether or not the oats have been sulphured, and if so, approximately to what degree. The moisture percentages will be found to vary considerably in the samples before and after sulphuring, according to the particular kind of method used. The weight per bushel, while not influenced materially, is found to be a little higher in most instances after sulphuring.

In the column headed "Oats appearing sound," it will be noticed that the percentage of such oats is increased considerably by bleaching, and in the column headed "Total oats appearing damaged," it is noticed that there is a corresponding decrease. In the column headed "Oats damaged by agencies other than heat," it is shown that in the sulphured samples the damage appears much less. In the last column, headed "Heat damaged oats," it is seen that while the percentage of heat damage in many instances is small, there is a corresponding reduction in this factor by the bleaching process.

By examining the table in detail, it is noted that the facts set forth in each set compare favorably with those in each of the other sets. In samples Nos. 88783 and 88830 it is shown that the total amount of oats appearing heat damaged was reduced from 54.8 to 31.4 per cent, a reduction of 23.4 per cent. In samples Nos. 89242 and 89245, however, it is seen that the total amount of oats appearing bin burned before sulphuring was 62 per cent while those appearing bin burned after sulphuring was 64.6 per cent.

¹ This method is given in detail in Circular 40, Bureau of Plant Industry, U. S. Department of Agriculture: "A Simple Method of Detecting Sulphured Barley and Oats," by W. P. Carroll, 1909; and in Circular 111, Bureau of Plant Industry, U. S. Department of Agriculture: "Improved Apparatus for Use in Detecting Sulphured Grain," by George H. Baston, 1913.

SUMMARY.

1. The sulphur bleaching of oats has been practiced during the past score of years, but the practice has increased during the last few years.

2. Investigations show that it is possible to bleach weather-stained, discolored, and damaged oats, giving them the appearance of natural oats of good quality.

3. It is possible to improve slightly the appearance of badly bin-burned and ground-damaged oats, thereby concealing a part of the damage.

4. The viability of oats is materially reduced by sulphur bleaching.

5. The methods used for bleaching are practically uniform throughout the oat-bleaching sections, with an occasional modification to meet the needs of individual operators.

6. The character of the season in which oats are harvested, whether a wet or dry season, has a direct influence upon the subsequent handling of the crop. Oats harvested in a dry season are rarely bleached, because they show little if any damage.

APPENDIX.

TABLE I.—*A comparison of oats before and after bleaching.*

[The figures shown in the table represent the analysis of samples as received, and the determination of other grain, seed, dirt, and foreign material has been omitted from the table.]

	Laboratory No.	Sulphur reaction.	Germination.	Moisture.	Weight per bushel.	Oats appearing sound.	Total oats appearing damaged.	Oats appearing damaged by agencies other than heat.	Oats appearing heat damaged.
Before sulphuring	87897	None....	<i>P. ct.</i> 56.0	<i>P. ct.</i> 12.9	<i>Lbs.</i> 30.25	<i>P. ct.</i> 50.4	<i>P. ct.</i> 45.2	<i>P. ct.</i> 39.2	<i>P. ct.</i> 6.0
After sulphuring	87898	Medium	.5	14.7	31.9	66.3	28.8	24.8	4.0
Before sulphuring	87899	None....	64.0	15.2	32.5	25.2	71.6	71.6	.....
After sulphuring (5 hours' standing).	87901	Medium .....	.....	15.7	33.1	37.6	56.4	56.4	.....
After sulphuring, after cooling....	87900	do....	.5	15.6	32.25	42.8	52.8	52.8	.....
Before sulphuring	87935	None....	64.0	14.0	33.7	49.2	48.8	47.6	1.2
After sulphuring (24 hours' standing).	87937	Medium	3.0	15.5	34.8	63.2	32.4	31.2	1.2
After sulphuring, after cooling....	87936	do....	10.0	15.5	34.0	70.6	23.6	22.8	.8
Before sulphuring	88074	None....	91.0	14.8	35.0	76.2	19.7	19.0	.7
After sulphuring, before cooling...	88075	Slight....	38.0	16.0	36.0	84.2	12.0	11.6	.4
After sulphuring, after cooling....	88076	Medium	45.2	15.7	34.9	86.0	11.0	11.0	Trace.
After sulphuring, cooling, and clipping.	88077	do....	49.0	15.3	36.5	84.4	11.6	11.0	.6
Before sulphuring, before clipping.	88087	None....	97.5	14.2	36.3	88.2	8.9	8.9	.....
Before sulphuring, after clipping...	88088	do....	94.5	14.4	39.25	88.1	8.9	8.9	.....
After sulphuring, after clipping....	88089	Medium	17.5	15.2	39.6	94.1	2.0	2.0	.....
After sulphuring, cooling, and clipping.	88090	do....	9.5	14.4	39.75	94.0	2.7	2.7	.....
Before sulphuring	88322	None....	93.6	14.2	39.25	83.0	12.0	12.0	.....
After sulphuring, before cooling...	88323	Medium	26.0	14.6	40.4	87.4	6.8	6.8	.....
After sulphuring, after cooling....	88324	do....	33.0	14.9	40.4	84.2	9.6	9.6	.....
Before sulphuring	88338	None....	91.5	13.8	38.0	77.8	19.6	19.2	.4
After sulphuring, before cooling...	88339	Slight....	1.5	14.3	38.6	88.2	9.3	9.3	.....
After sulphuring, after cooling....	88340	do....	5.5	13.8	38.25	87.2	9.5	9.5	Trace.
Before sulphuring	88460	None....	95.5	14.6	37.2	89.0	7.6	7.6	.....
After sulphuring, before cooling...	88461	Heavy....	39.0	14.9	37.7	93.1	2.6	2.6	.....
After sulphuring, after cooling....	88462	do....	29.5	15.1	37.7	92.5	4.2	4.2	Trace.
Before sulphuring	88528	None....	95.0	14.4	38.7	73.8	22.9	22.9	.....
After sulphuring, before cooling...	88529	Slight....	82.0	15.4	40.9	92.6	5.2	5.2	.....
After sulphuring, after cooling....	88530	do....	77.0	14.8	40.5	87.9	9.8	9.8	.....
Before sulphuring	88531	None....	94.5	14.5	39.9	83.8	13.6	13.6	.....
After sulphuring, before cooling...	88532	Medium	73.0	15.3	38.7	92.0	5.4	5.2	.2
After sulphuring, after cooling....	88533	Slight....	78.0	15.2	39.0	89.2	8.5	8.2	.3
Before sulphuring	88534	None....	94.0	14.6	39.0	82.6	14.6	14.2	.4
After sulphuring, before cooling...	88535	Medium	.5	16.0	39.0	93.6	4.4	4.4	.....
After sulphuring, after cooling....	88536	do....	44.0	15.2	39.3	90.8	7.2	7.2	.....
Before sulphuring	87796	None....	53.0	.....	.....	53.2	43.2	36.8	6.4
After sulphuring (from sulphur tower).	87798	Heavy....	.....	.....	.....	66.9	29.2	23.8	5.4
After sulphuring (24 hours' standing).	87797	Medium	.5	.....	34.0	67.9	29.2	16.4	12.8
Before sulphuring (dried and clipped).	87799	None....	46.0	.....	38.0	45.3	52.7	28.5	24.2
After sulphuring (from sulphur tower).	87801	Medium	13.0	.....	38.0	48.6	48.5	23.4	25.2
After sulphuring (24 hours' standing).	87800	Heavy....	13.0	.....	37.5	60.2	38.2	20.2	18.0
Before sulphuring (dried and clipped).	87802	None....	41.0	.....	37.5	46.4	51.2	29.6	21.6
After sulphuring (from sulphur tower).	87804	Medium	21.0	.....	35.5	56.8	40.8	17.2	23.6
After sulphuring (24 hours' standing).	87803	Slight....	24.0	.....	36.0	71.2	27.6	12.8	14.8

TABLE I.—A comparison of oats before and after bleaching—Continued.

	Laboratory No.	Sulphur reaction.	Germination.	Moisture.	Weight per bushel.	Oats appearing sound.	Total oats appearing damaged.	Oats appearing damaged by agencies other than heat.	Oats appearing heat damaged.
Before sulphuring (clipped).....	87843	None.....	<i>P. ct.</i> 44.0	<i>P. ct.</i> -----	<i>Lbs.</i> 39.0	<i>P. ct.</i> 46.4	<i>P. ct.</i> 51.6	<i>P. ct.</i> 26.4	<i>P. ct.</i> 25.2
After sulphuring (from sulphur tower).	87844	Slight.....	-----	-----	38.0	46.6	51.8	29.2	21.6
After sulphuring (24 hours' standing).	87845	do.....	9.0	-----	38.25	45.8	52.2	27.8	24.4
Before sulphuring.....	87869	None.....	1.0	15.7	33.5	12.2	85.8	7.6	77.2
After sulphuring (from sulphur tower).	87870	Heavy.....	-----	17.2	34.5	18.5	80.5	8.6	71.9
After sulphuring (24 hours' standing).	87871	do.....	-----	16.5	33.5	26.0	72.4	8.4	64.0
Before sulphuring.....	87892	None.....	61.0	12.2	32.9	60.8	36.5	24.6	11.9
After sulphuring (from sulphur tower).	87893	Heavy.....	-----	21.3	32.75	73.6	24.8	18.4	6.4
After sulphuring (24 hours' standing).	87894	do.....	7.0	15.4	36.0	77.5	21.7	15.1	6.6
Before sulphuring.....	87902	None.....	50.0	13.3	38.5	49.3	49.6	19.2	30.4
After sulphuring (from sulphur tower).	87903	Medium.....	22.0	17.8	36.5	61.3	36.7	17.5	19.2
After sulphuring (24 hours' standing).	87904	do.....	14.0	17.1	36.5	55.2	43.6	18.8	24.8
Before sulphuring.....	87939	None.....	80.0	-----	-----	49.6	48.8	48.8	-----
After sulphuring.....	87940	Medium.....	.5	-----	-----	70.8	28.0	25.2	2.8
After sulphuring and clipping.....	87941	do.....	58.0	-----	-----	68.6	29.8	29.0	.8
Before sulphuring.....	87942	None.....	14.0	-----	-----	20.0	75.4	22.3	53.1
After sulphuring.....	87943	Heavy.....	.5	-----	-----	60.3	37.0	21.2	15.8
After sulphuring and clipping.....	87944	do.....	.5	-----	-----	58.5	39.9	18.5	20.4
Before sulphuring.....	87945	None.....	88.0	-----	-----	59.2	39.4	38.8	.6
After sulphuring.....	87946	Medium.....	3.0	-----	-----	74.2	24.2	19.6	4.6
After sulphuring and clipping.....	87947	None.....	80.0	-----	-----	65.0	33.2	28.4	4.8
<i>Graded No. 3 White oats.</i>									
Before sulphuring.....	88605	do.....	89.0	14.3	36.0	79.6	16.0	11.2	4.8
After sulphuring (from sulphur tower).	88639	Medium.....	84.0	15.7	36.5	92.6	5.2	5.2	Trace.
After sulphuring (1 hour's standing).	88606	do.....	76.0	15.4	37.0	92.4	4.8	4.8	Trace.
After sulphuring, before cooling.....	88607	do.....	56.5	15.0	36.0	90.8	6.0	5.2	.8
After sulphuring, after cooling.....	88608	do.....	89.0	14.6	40.75	84.4	12.4	10.0	2.4
After sulphuring and clipping.....	88609	do.....	67.0	14.8	41.0	83.2	13.6	12.0	1.6
<i>Graded No. 3 White oats.</i>									
Before sulphuring.....	88610	None.....	63.0	15.2	37.0	88.8	8.8	7.2	1.6
After sulphuring (from sulphur tower).	88611	Medium.....	9.0	15.7	39.8	92.8	6.0	5.6	.4
After sulphuring, before cooling.....	88640	do.....	53.5	15.7	40.5	90.6	7.8	7.0	.8
After sulphuring, after cooling.....	88612	do.....	66.0	15.3	39.5	88.0	8.8	8.0	.8
<i>Bin-burned oats.</i>									
Before sulphuring.....	88672	None.....	21.0	14.0	35.5	28.0	69.2	18.4	50.4
After sulphuring (from sulphur tower).	88673	Medium.....	-----	14.7	35.5	44.4	51.6	12.8	38.8
After sulphuring, before cooling.....	88696	do.....	-----	15.0	35.8	54.0	43.2	10.8	32.4
After sulphuring, after cooling.....	88697	do.....	-----	14.5	35.6	56.0	41.2	8.8	32.4
<i>Graded No. 3 White oats.</i>									
Before sulphuring.....	88670	None.....	79.5	14.2	32.0	62.4	35.6	33.6	2.0
After sulphuring (from sulphur tower).	88671	Medium.....	22.5	15.1	32.0	26.0	21.6	20.4	1.6
After sulphuring, before cooling.....	88698	do.....	26.0	15.3	31.8	79.6	17.6	16.4	1.2
After sulphuring, after cooling.....	88699	do.....	44.5	15.4	32.25	80.2	17.4	14.0	3.4

TABLE I.—*A comparison of oats before and after bleaching—Continued.*

	Laboratory No.	Sulphur reaction.	Germination.	Moisture.	Weight per bushel.	Oats appearing sound.	Total oats appearing damaged.	Oats appearing damaged by agencies other than heat.	Oats appearing heat damaged.
<i>Graded No. 4 White oats.</i>									
Before sulphuring	88781	None	P. ct. 61.0	P. ct. 12.3	Lbs. 33.25	P. ct. 76.0	P. ct. 22.8	P. ct. 21.6	P. ct. 1.2
After sulphuring (from sulphur tower).	88782	Slight	17.5	17.1	33.25	82.4	15.6	14.8	.8
<i>Graded No. 4 White oats, clipped.</i>									
Before sulphuring	88757	None	67.5	13.6	35.0	79.2	19.6	16.8	2.8
After sulphuring (from sulphur tower).	88758	Heavy	9.5	16.6	38.0	94.8	4.0	4.0	-----
After sulphuring (24 hours' standing).	88773	Slight	45.5	16.0	37.6	89.6	8.8	8.0	.8
After sulphuring (24 hours' standing—steam).	88774	---do	27.5	16.5	37.5	89.8	9.4	7.6	1.8
<i>Bin-burned oats.</i>									
Before sulphuring	88783	None	10.5	12.1	33.25	28.0	69.6	14.8	54.8
Before sulphuring, clipped	88784	---do	14.5	12.2	36.0	26.0	71.2	13.2	58.0
After sulphuring, clipped (from sulphur tower).	88785	Medium	1.5	18.2	33.0	45.0	52.0	13.6	38.4
After sulphuring, clipped (from sulphur tower—steam).	88786	Heavy	-----	25.5	30.25	39.8	55.6	12.8	32.8
After sulphuring, clipped (24 hours' standing).	88830	---do	9.0	16.7	35.7	53.0	45.0	13.6	31.4
<i>Clipped White oats.</i>									
Before sulphuring	88846	None	82.0	14.5	40.4	92.4	6.4	4.4	Trace.
After sulphuring (from sulphur tower).	88847	Heavy	-----	18.6	36.7	92.4	6.4	5.6	.8
After sulphuring (24 hours' standing).	88848	---do	14.5	18.3	37.3	89.2	9.6	8.0	1.6
<i>Graded No. 3 White oats.</i>									
Before sulphuring	88726	None	70.5	14.2	-----	87.6	11.6	10.0	1.6
After sulphuring (from sulphur tower).	88727	Medium	-----	14.8	-----	72.0	23.6	13.2	10.0
After sulphuring (loading into car)	88728	---do	33.0	16.0	-----	71.6	25.2	14.4	10.8
<i>Graded No. 3 White oats.</i>									
Before sulphuring	89231	None	90.5	12.4	33.0	82.0	12.8	12.4	.4
After sulphuring (from sulphur tower).	89232	Slight	84.5	12.8	34.0	93.0	3.6	3.2	.4
After sulphuring, before cooling	89240	---do	82.5	13.0	35.3	89.2	4.4	4.4	-----
After sulphuring, after cooling	89241	---do	77.0	12.7	34.7	86.8	6.0	6.0	-----
<i>Bin-burned oats.</i>									
Before sulphuring	89242	None	5.5	12.7	34.6	14.4	82.8	20.8	62.0
After sulphuring (from sulphur tower).	89243	Slight	-----	13.1	34.6	34.6	62.4	8.4	54.0
After sulphuring, before cooling	89244	---do	-----	13.1	36.5	37.6	61.2	17.2	44.0
After sulphuring, after cooling	89245	---do	1.5	13.1	35.6	26.6	70.2	5.6	64.6
<i>Graded No. 3 White oats.</i>									
Before sulphuring	89139	None	90.0	12.0	30.0	81.2	14.0	14.0	-----
After sulphuring (from sulphur tower).	89140	Slight	77.0	12.7	27.3	87.0	7.6	7.2	.4
After sulphuring (24 hours' standing).	89143	---do	84.0	15.5	25.0	78.0	10.8	10.8	-----
<i>Graded No. 3 White oats, clipped.</i>									
Before sulphuring	89141	None	95.5	12.6	32.3	86.0	9.2	9.2	-----
After sulphuring (from sulphur tower).	89142	Slight	-----	17.8	27.3	88.0	9.2	9.2	-----
After sulphuring (24 hours' standing).	89144	---do	42.0	19.1	28.7	88.8	7.2	7.2	-----

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PROFESSIONAL PAPER

August 30, 1918

TYPICAL SPECIFICATIONS FOR NON-
BITUMINOUS ROAD MATERIALS

By

PRÉVOST HUBBARD, Chemical Engineer, and
FRANK H. JACKSON, JR., Assistant Testing Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 707

Contribution from the Bureau of Entomology
L. O. HOWARD, Chief

Washington, D. C.

PROFESSIONAL PAPER

August 26, 1918

RESULTS OF EXPERIMENTS WITH
MISCELLANEOUS SUBSTANCES AGAINST BED-
BUGS, COCKROACHES, CLOTHES MOTHS, AND
CARPET BEETLES

By

E. W. SCOTT, Entomologist, Enforcement Insecticide Act
and W. S. ABBOTT and J. E. DUDLEY, Jr., Scientific
Assistants, Bureau of Entomology

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 711

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.

PROFESSIONAL PAPER

November 14, 1918

LOGGING IN THE DOUGLAS FIR
REGION

By

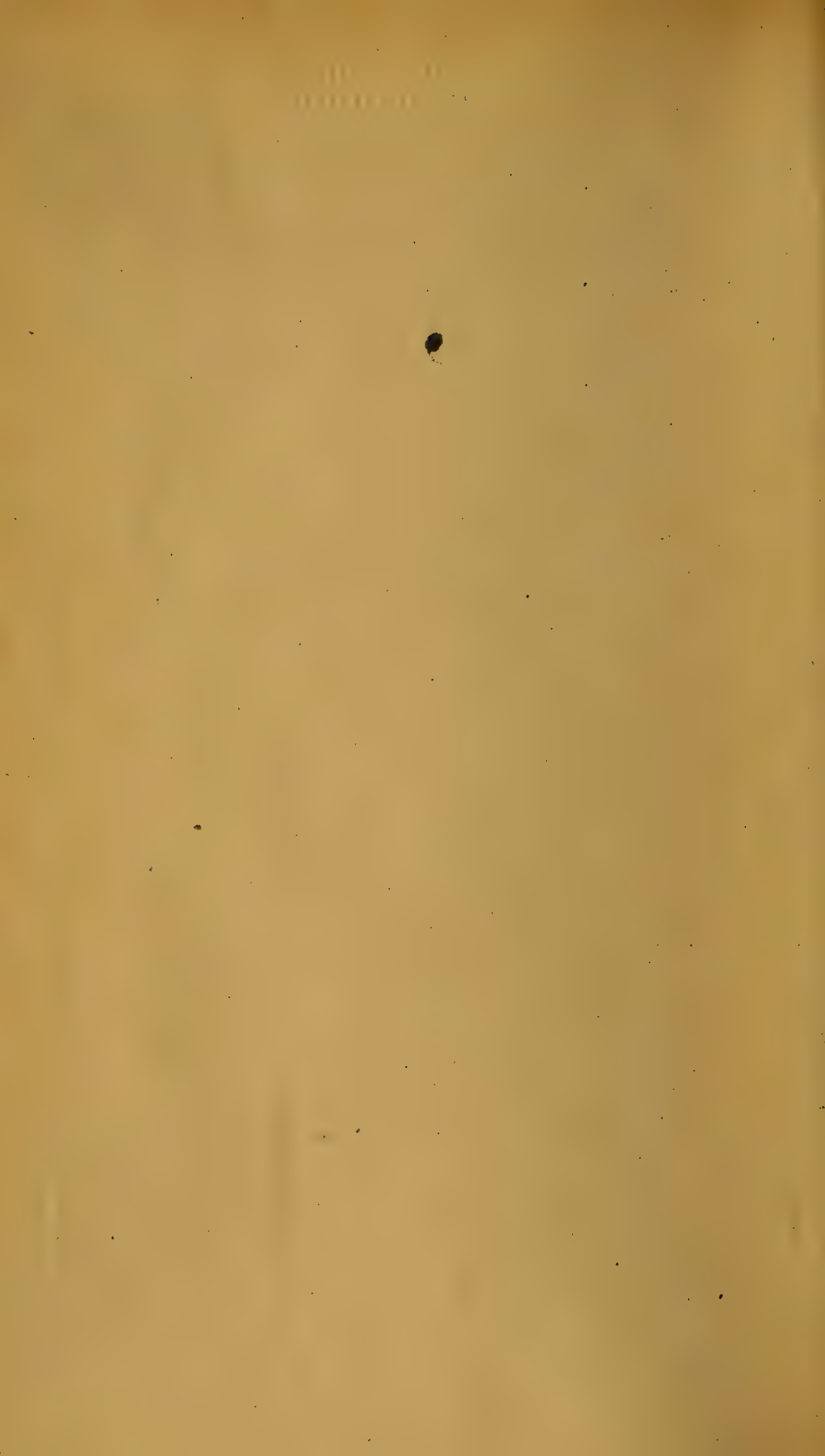
WILLIAM H. GIBBONS, Forest Examiner

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 716

OFFICE OF THE SECRETARY

Contribution from the Office of Farm Management
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Washington, D. C.

PROFESSIONAL PAPER

September 26, 1918

A FIVE-YEAR FARM MANAGEMENT
SURVEY IN PALMER TOWNSHIP
WASHINGTON COUNTY, OHIO, 1912-1916

By

H. W. HAWTHORNE, Scientific Assistant

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 718

Contribution from the Forest Service
HENRY S. GRAVES, Forester

Washington, D. C.



December 17, 1918

SMALL SAWMILLS

Their Equipment, Construction, and Operation

By

DANIEL F. SEEREY, Logging Engineer

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 720

Contribution from the Bureau of Biological Survey
E. W. NELSON, Chief

Washington, D. C. PROFESSIONAL PAPER December 23, 1918

FOOD HABITS OF THE MALLARD
DUCKS OF THE UNITED STATES

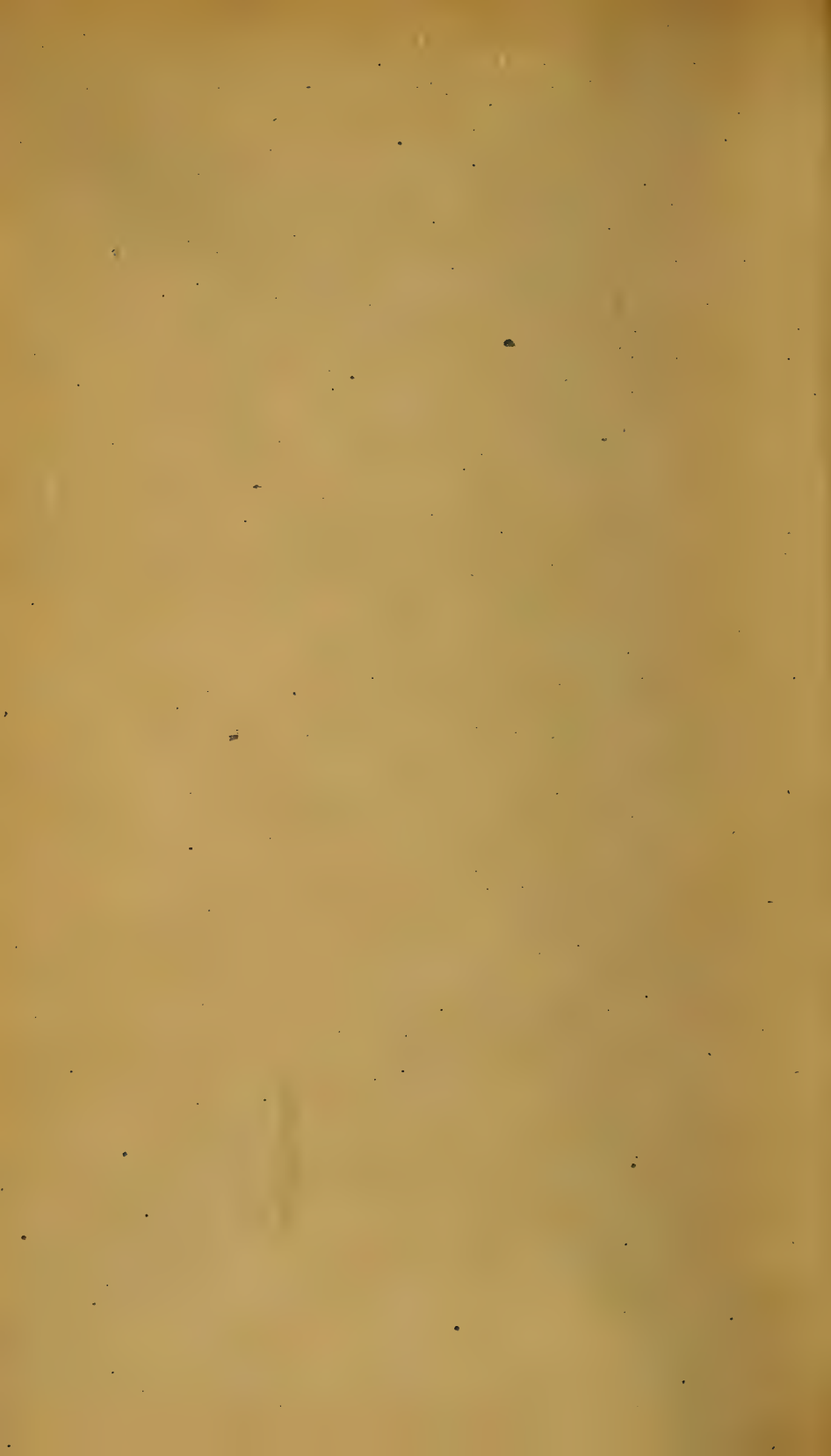
By

W. L. MCATEE, Assistant Biologist

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UNITED STATES DEPARTMENT OF AGRICULTURE
BULLETIN No. 721

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

November 22, 1918

THE BEET-SUGAR INDUSTRY IN THE
UNITED STATES

By

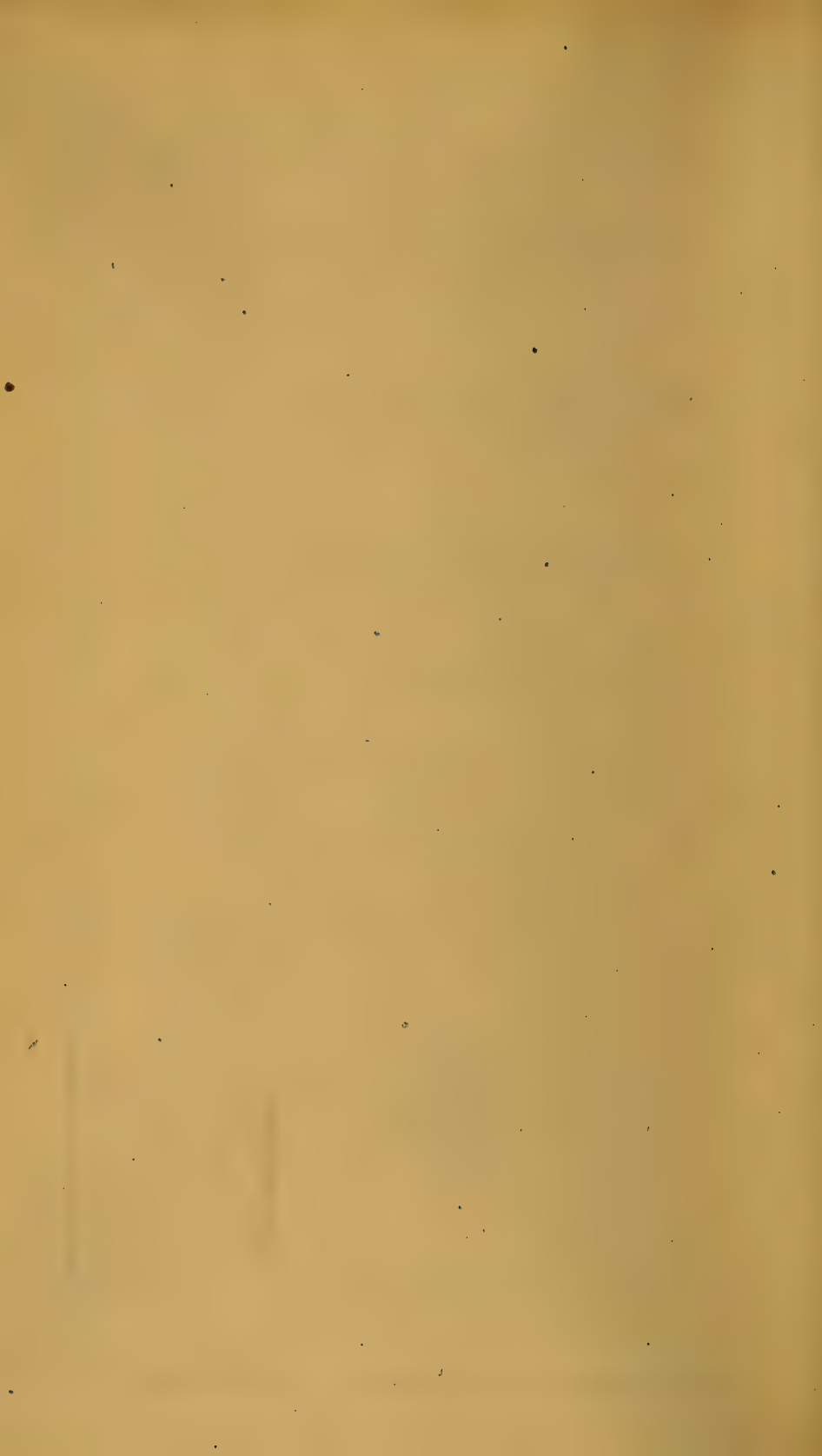
C. O. TOWNSEND, Pathologist in Charge,
Office of Sugar-Plant Investigations

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UNITED STATES DEPARTMENT OF AGRICULTURE

BULLETIN No. 722

Contribution from the Bureau of Plant Industry
WM. A. TAYLOR, Chief

Washington, D. C.

PROFESSIONAL PAPER

October 22, 1918

A STUDY OF HEART-ROT IN
WESTERN HEMLOCK

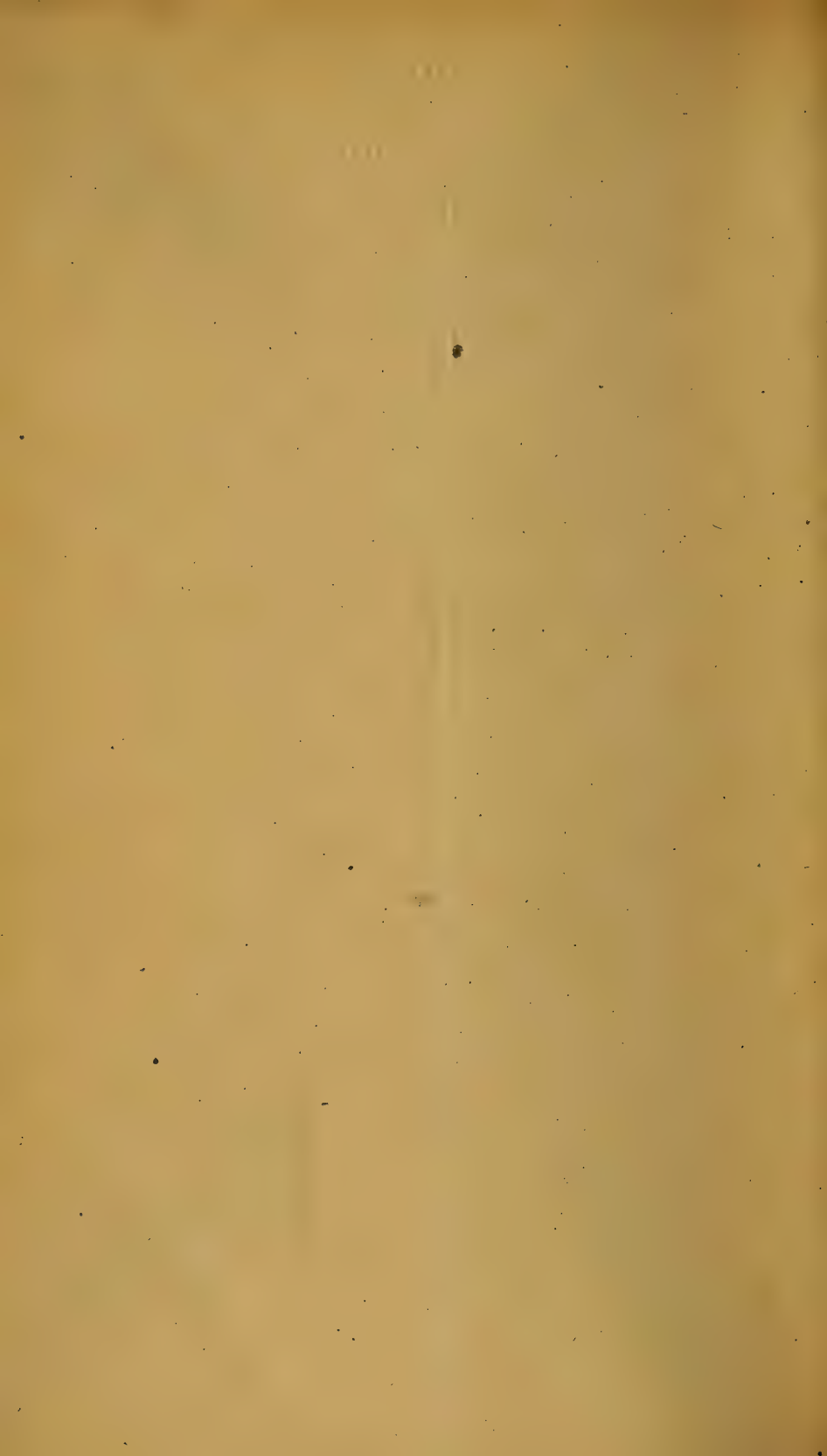
By

JAMES R. WEIR, Forest Pathologist, and ERNEST E. HUBERT
Scientific Assistant, Office of Investigations in Forest Pathology

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BULLETIN No. 724

Contribution from the Bureau of Public Roads.
LOGAN WALLER PAGE, Director

Washington, D. C.

PROFESSIONAL PAPER

December 21, 1918

DRAINAGE METHODS AND
FOUNDATIONS FOR COUNTY ROADS

By

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CHARLES H. MOOREFIELD, Senior Highway Engineer

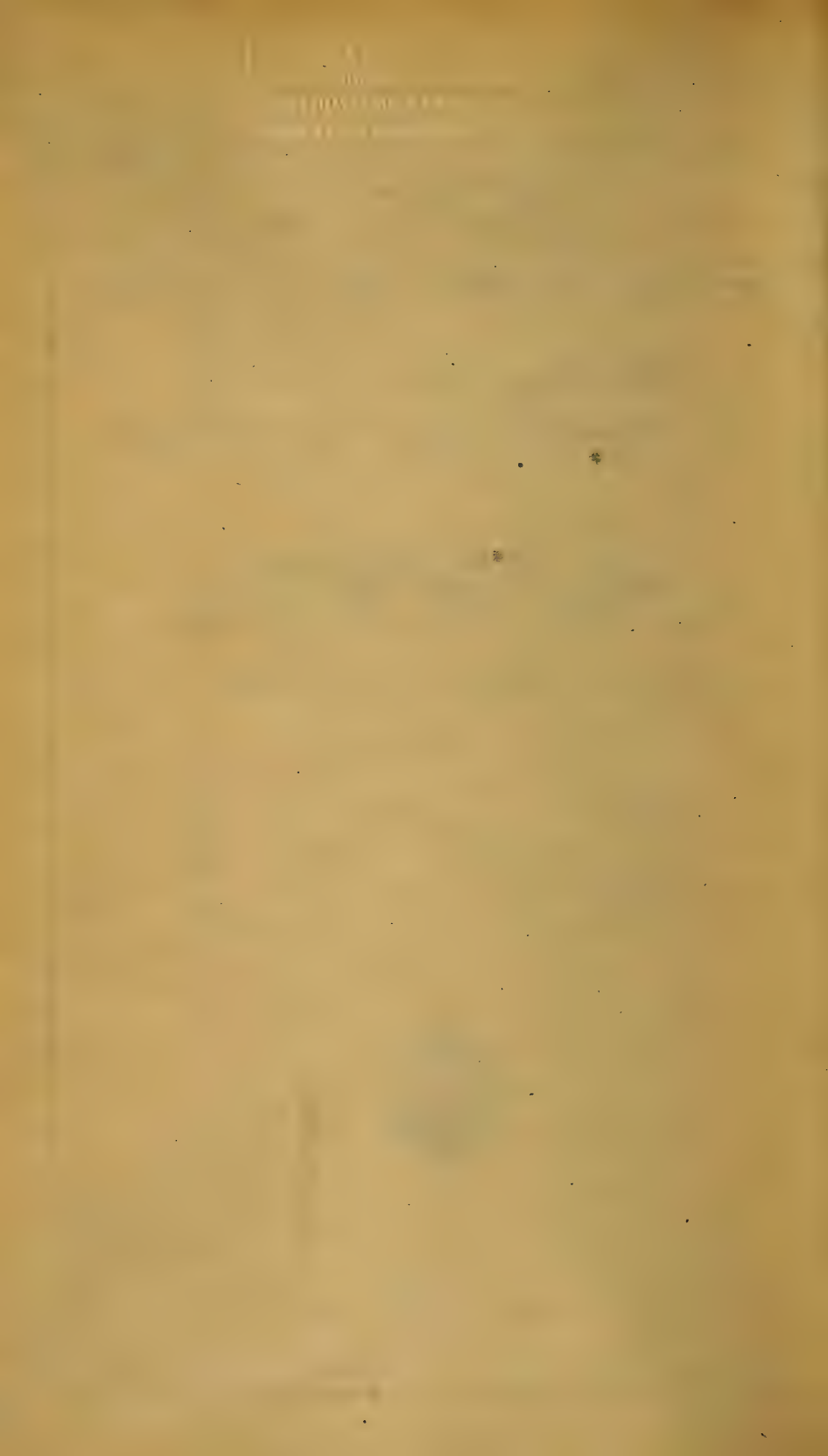
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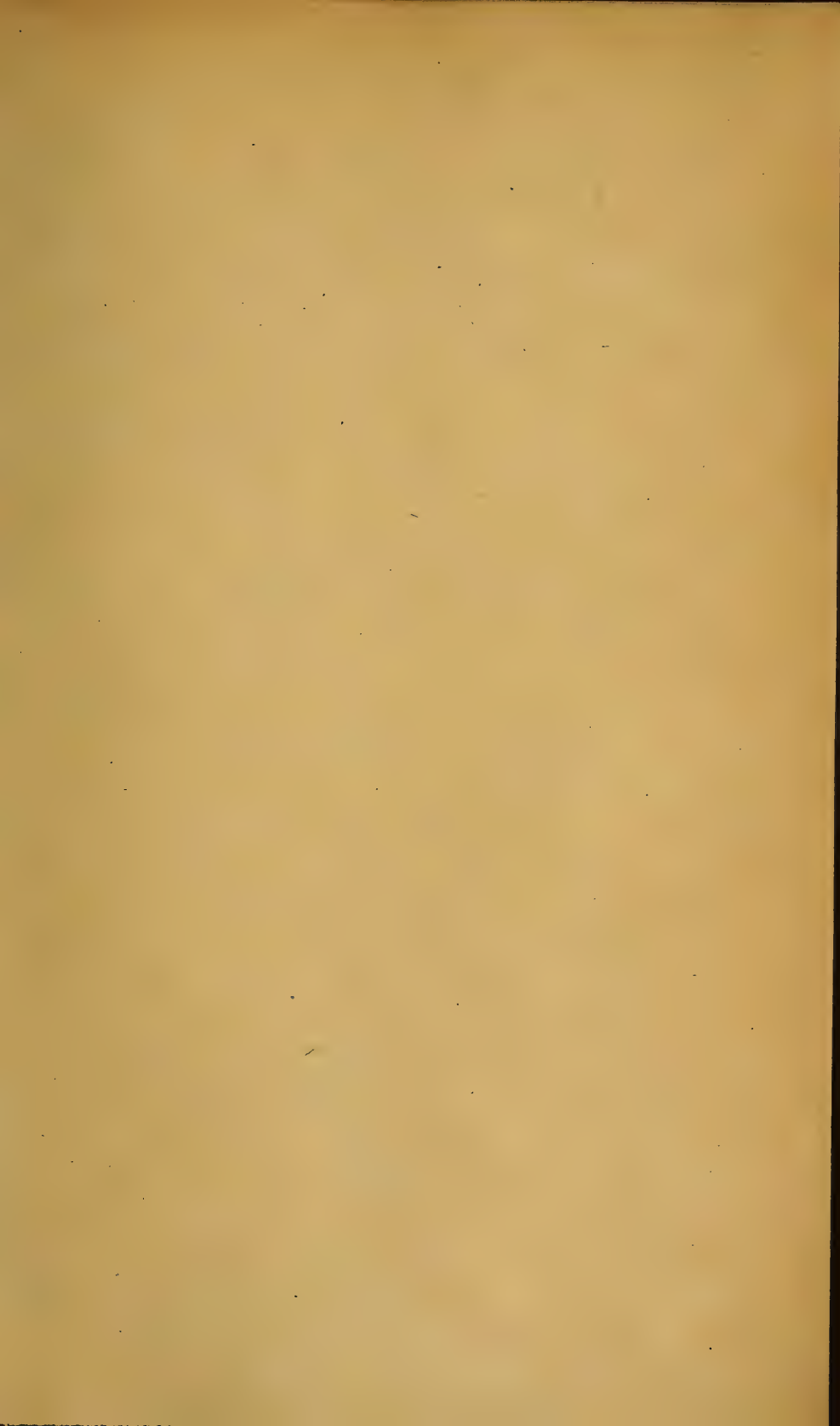
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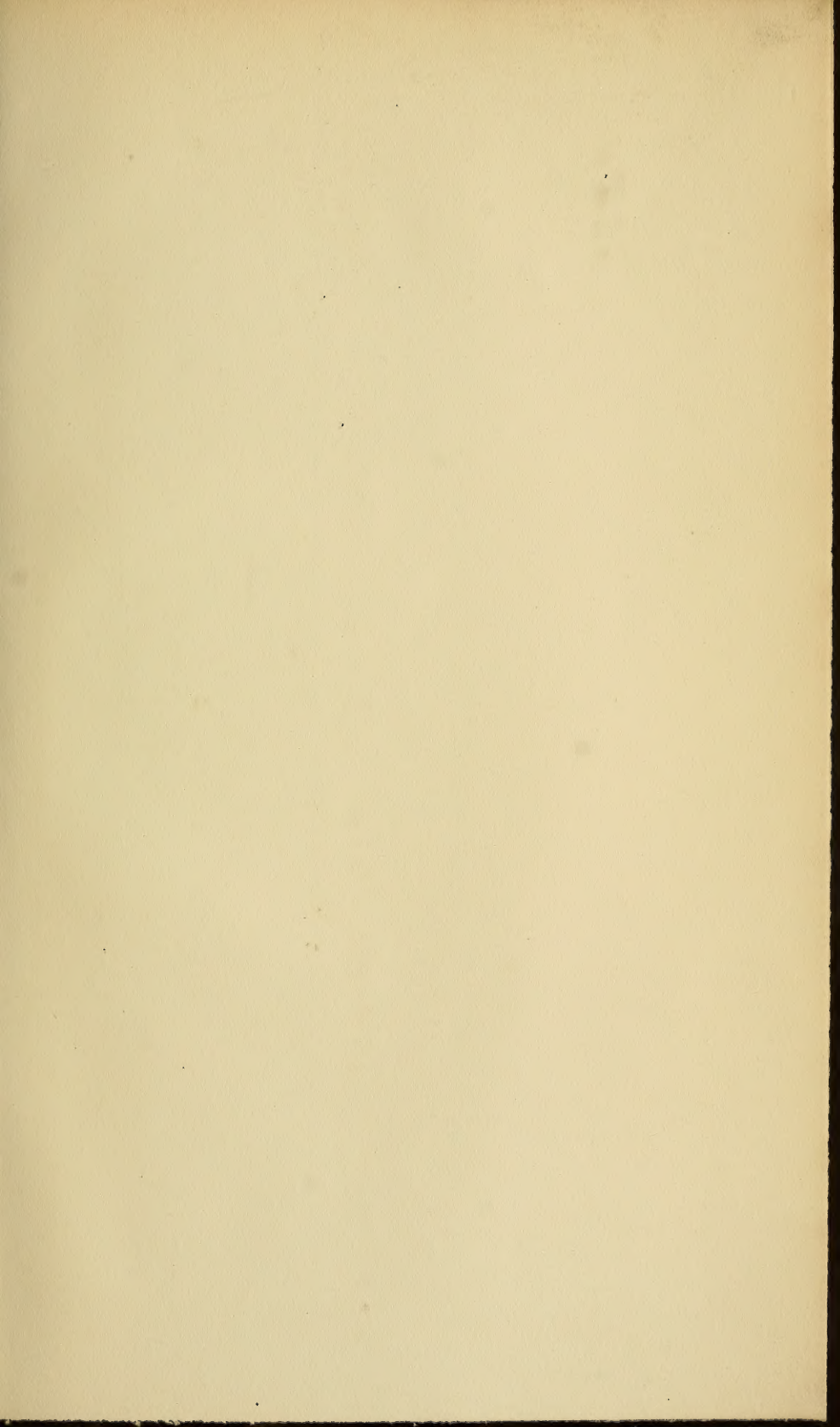


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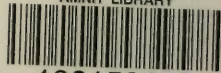








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